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PARAHO OIL SHALE DEMONSTRATION

MINING OPERATIONS

FINAL REPORT
VOLUME 2

PARAHO OIL SHALE DEMONSTRATION

MINING OPERATIONS

FINAL REPORT

Prepared

By

THE CLEVELAND-CLIFFS IRON COMPANY
DEVELOPMENT ENGINEERING, INC.

For

PARAHO OIL SHALE DEMONSTRATION, INC.
300 Enterprise Building
Grand Junction, Colorado 81501

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FOREWORD

Under a lease approved by the President of the United States in May, 1972, Paraho undertook, in cooperation with the federal government, to demonstrate the engineering, economic and environmental feasibility and desirability of the Paraho processes and hardware for retorting oil shale. This Final Report to participants of the Paraho Oil Shale Demonstration is a six-volume document that describes the research and development operations, the engineering design and cost estimating, and the commercial evaluation studies carried out from late-1973 to mid-1976.

THIS VOLUME 2 IS CONSIDERED CONFIDENTIAL UNDER THE TERMS OF THE PARTICIPANTS AGREEMENTS WITH PARAHO CORPORATION AND DEVELOPMENT ENGINEERING, INC. MORE-OVER, BECAUSE OF THE COMMITMENT TO THE GOVERNMENT NOT TO PUBLISH INFORMATION PREMATURELY, DISTRIBUTION SHOULD BE STRICTLY CONTROLLED ON A NEED-TO-KNOW BASIS UNTIL AFTER THIS MATERIAL HAS BEEN PUBLISHED BY THE GOVERNMENT OR PARAHO.

The field operations were conducted at the Anvil Points Oil Shale Research Facilities located on the Naval Oil Shale Reserves near Rifle, Colorado. Administration of these leased facilities was transferred from the Bureau of Mines (BOM) to the Energy Research and Development Administration (ERDA) when the latter agency was formed in 1974.

The Paraho Oil Shale Demonstration was privately sponsored by the following seventeen participants at a total cost of \$9.4 million:

Sohio Petroleum Company
Southern California Edison Company
The Cleveland-Cliffs Iron Company
Gulf Oil Corporation

Arthur G. McKee and Company
Kerr-McGee Corporation
Shell Development Corporation
Standard Oil Company (Indiana)
The Carter Oil Company (Exxon)
Mobil Research and Development Corporation
Webb-Gary-Chambers-McLoraine (Group)
Sun Oil Company
Texaco Inc.
Phillips Petroleum Company
Atlantic Richfield Company
Marathon Oil Company
Chevron Research Company

These participants received the right to license Paraho's oil shale technology on favorable terms for their support and cooperation which are gratefully acknowledged.

The results of Paraho's operations at Anvil Points are encouraging. They demonstrate that the process works, that the equipment is operable and durable, that thermal efficiencies and yields are high, and that the entire system developed is environmentally acceptable. The extended periods of Paraho retort operations and the results obtained demonstrate this. The evidence includes the 77-day Pilot Plant run and the 56-day Semi-Works run, both of which were terminated voluntarily.

After the 56-day retort run, 10,000 barrels of Paraho crude shale oil were shipped to the nearby Gary Western Refinery and converted into military products. This federally funded work was done for the U.S. Navy's Energy and Natural Resources Research and Development Office. That Office coordinated the refining and the nationwide, refined product testing program and publishing a report entitled:

Production and Refining of 10,000 Bbl. Paraho Crude Shale Oil Into Military Fuels, U. S. Navy Contract #N0014-75-C-0055

A retorted shale management research project jointly funded by the Bureau of Mines and Paraho will be completed in late-1976 at an estimated additional cost of $0.5 million. At that time, a report entitled, "Retorted Shale Management", will be issued as the concluding volume of this report.

Paraho

PARAHO OIL SHALE DEMONSTRATION

MINING OPERATIONS

FINAL REPORT

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1. INTRODUCTION

The Cleveland-Cliffs Iron Company (Cliffs), one of the initial participants in the Paraho Oil Shale Demonstration, provided Development Engineering, Inc. (DEI) with preliminary mine plans and costs to develop the demonstration program at Anvil Points. Initially, DEI planned to subcontract only the mining for the project to Cliffs. This would have included mining equipment maintenance which Cliffs was well qualified to perform. In the interest of efficiency, it was decided to add all maintenance to Cliffs responsibilities under DEI's management supervision. Since this gave Cliffs responsibility for most labor procurement, rather than duplicate labor personnel services, Cliffs was requested to handle the procurement of operating labor as well. This labor operated under DEI's direct supervision.

Cliffs and DEI worked together to obtain the necessary approvals and permits for mine startup. This report deals only with mining operations.

Two areas, adjacent to the U. S. Bureau of Mines' (U.S.B.M.) Demonstration Mine, had been investigated as potential locations for the new mining effort. One plan envisioned extraction of shale from an area immediately east of the Demonstration Mine, utilizing #3 portal as access. A second plan proposed

mining an area to the north, using #1 portal and Able Drift as a means of entry. The second plan was selected to supply ore for the project because of lower preproduction cost, easier access to the zone of interest, and reduced ventilation problems (see Figure 1-1).

Between August, 1974, and December, 1975, a total of 101,490 tons of oil shale were mined for processing. The shale, after crushing and screening, was used as feed for the Paraho retort. Mine preproduction work had been started in mid-January, 1974. Activity at the mine, except for some hauling of stockpiled material, ceased on December 15, 1975.

The primary function of the mining effort was to supply oil shale for the Paraho Oil Shale Demonstration. However, during the period, Man/Machine Work Studies of all mining functions were made and several types of drill equipment and a mechanical scaler were tested for their applicability to oil shale mining. An evaluation study to determine the percent of -½" product resulting from blasting and crushing oil shale to -3" +½" was conducted also. Detailed reports of work studies of individual mining functions and equipment testing are included in the Appendix.

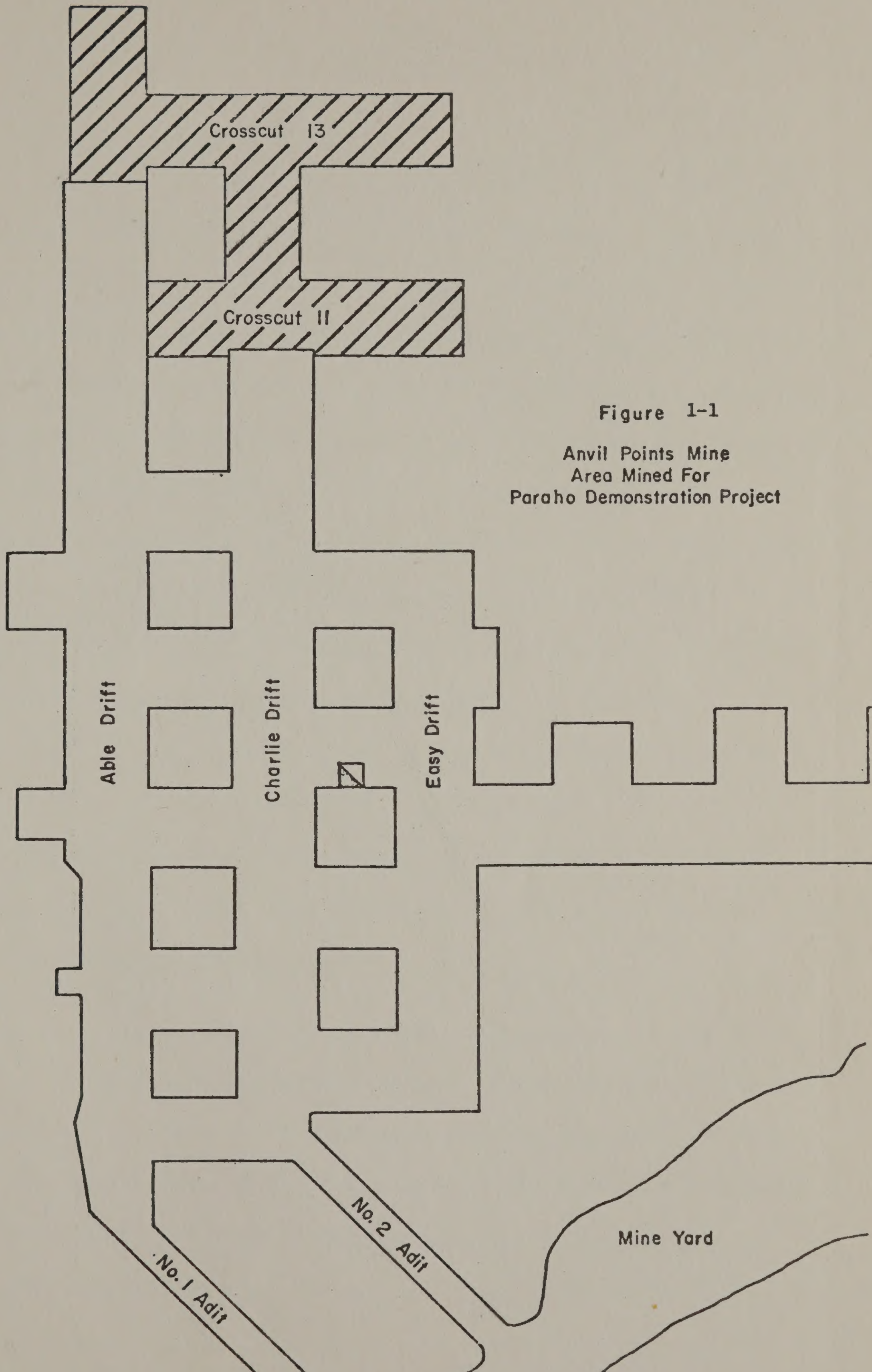

Figure 1-1

Anvil Points Mine
Area Mined For
Paraho Demonstration Project

2. PREMINING ACTIVITY

3. PRODUCTION MINING

4. INDUSTRIAL ENGINEERING

5. APPENDIX

2. PREMINING ACTIVITY

2.1 Roof Examination and Control

Prior to final acceptance of Able Drift as an access way into the mining area, the roof over the entry was carefully inspected. Jointing and fractures were mapped. Comparisons made with similar information, compiled by the U.S.B.M. team years before, showed that little change had taken place. Inspection of five old stratiscope holes and comparison with Bureau's records indicated only minimal changes in roof strata partings had occurred. Sagmeters, that had been placed in the roof ten years earlier, were checked. Here too, readings compared favorably with those on record, reemphasizing the stable condition of the mine roof. As a final precaution, seven core holes, 25 to 30 feet deep, were drilled into the roof over Able Drift at approximate 120 foot intervals. Core from these holes showed the roof rock to be competent and parting frequency to be within acceptable limits.

After ascertaining roof stability, miners were assigned the task of roof control improvement. The roof bolts in Able Drift were checked with a torque wrench and retightened, as needed, to provide maximum effectiveness. Since existing bolts were widely spaced, additional bolts were installed to obtain a five foot by five foot spacing pattern.

Approximately 800 additional roof bolts were placed as a precautionary roof control measure. Loose rock was scaled from the roof and ribs as the bolting operation proceeded from the portal toward the new mining area.

2.2 Mine Road Repair

The road between the mine and the crushing plant is 5.2 miles long. Four hairpin switchbacks are located along its upper portion. Much of the gradient is at -10% as the travel way descends from the mine elevation of 8,200 feet to the plant at 6,000 feet above sea level. Prior to plant startup, many spots along the road were found to be too narrow to accommodate the 50 ton trucks being scheduled for use on the oil shale haul.

Several of the narrow spots were made usable by simply dozing and ripping material from the inside near vertical banks. One stretch required drilling and blasting to accomplish this end. In several areas, steel piling was driven along the outer edge of the roadway to support cribbing and fill, thus extending the road shoulders by six feet or more. A number of culverts were extended to prevent washing of replaced shoulder fill. After the repair work was completed, the entire road received a top dressing of crushed river gravel and crushed oil shale.

The improved road still did not meet the new State and Federal safety standards set for elevated mine roadways. To be in full compliance, run outs were needed at each switchback and outside shoulders required berms or guardrails. The road was not wide enough to berm and to make it so, would require complete rebuilding. Berms or guardrails would, in addition, interfere with snow removal efforts and, due to physical limitations at switchback locations, run outs could not be constructed unless major amounts of money were committed. A variance permitting use of the road, without further modification, was applied for and received prior to plant startup.

2.3 <u>Mine Equipment Acquisition</u>

Specialized equipment needed to activate the mine acquired in the months preceding actual mine startup. A need to minimize the cost of mining oil shale for the Paraho project resulted in considerable "shopping" to obtain the required machinery.

2.3.1 Usable equipment left from the U. S. Bureau of Mines' activities at Anvil Points included a compressor, two water trucks, an aerial platform, and two motor graders. These were renovated by the maintenance group. The aerial platform was modified for use as an explosives loader.

2.3.2 A drill jumbo, equipped for rotary drilling, was rented from the Colony Development Operation. The single boomed rig had been used in the Mobil Mine before being purchased by Colony.

2.3.3 A used Gradall mechanical scaler was located in Boise, Idaho and purchased for the project.

2.3.4 Two 50 ton capacity Hough 350 Payhaulers and a Hough six yard 560 Payloader were purchased new for the loading and hauling functions. The Payhauler's four-wheel drive feature was felt to be of benefit because of adverse haul conditions between mine and plant.

2.3.5 A roof bolter, ventilation fan and semi-portable substation were purchased from the Mobil Mine group.

2.4 Other Premining Activities

Prior to mine startup, the 100,000 cfm mine fan and approximately 800 feet of six foot diameter tubing were installed to provide ventilation to the mining area. An 800 cfm compressor was installed in Crosscut #6 and an electrical substation was set up in Crosscut #8. Air and water were piped to the mining faces. Power lines were hung, as needed, to points of usage.

Early in the program, several attempts were made to re-activate a system that had supplied water to the mine from reservoirs located on the mesa above the mine. The efforts included dam repair and equipment replacement. Ultimately, the project was abandoned when it became apparent that the ponds would require dredging. Throughout the period of mine activity, water, required by the mining operation, was hauled from the plant.

3. PRODUCTION MINING

4. INDUSTRIAL ENGINEERING

5. APPENDIX

Parahl

3. PRODUCTION MINING

3.1 Mining Function Description

3.1.1 Drilling: Face drilling was handled by a Gardner-Denver Prototype, single boomed jumbo. Drilling action was straight rotary. The machine was capable of drilling 30 foot deep blastholes, though most drilling in the program was limited to holes less than 25 feet in depth. The standard drill pattern consisted of a V-cut round of 26 4-¼" diameter holes in a mine face that was 55 feet wide and 40 feet high (see Figure 3-1). The drill rounds blasted during the program pulled an average depth of 18.2 feet and produced 2,670 tons.

3.1.2 Charging and Blasting: Blasthole charging utilized an ammonium nitrate and fuel oil mixture as a primary blasting agent. The AN/FO was pneumatically blown into holes from a pressure pot of 400 pounds capacity. Blasters worked from an elevating platform to charge holes in the 40 foot high faces.

Special charging techniques were practiced when loading rib holes. Two inch cardboard tubes, placed in the holes, were filled with AN/FO, leaving an uncharged space between the tube and the wall of the

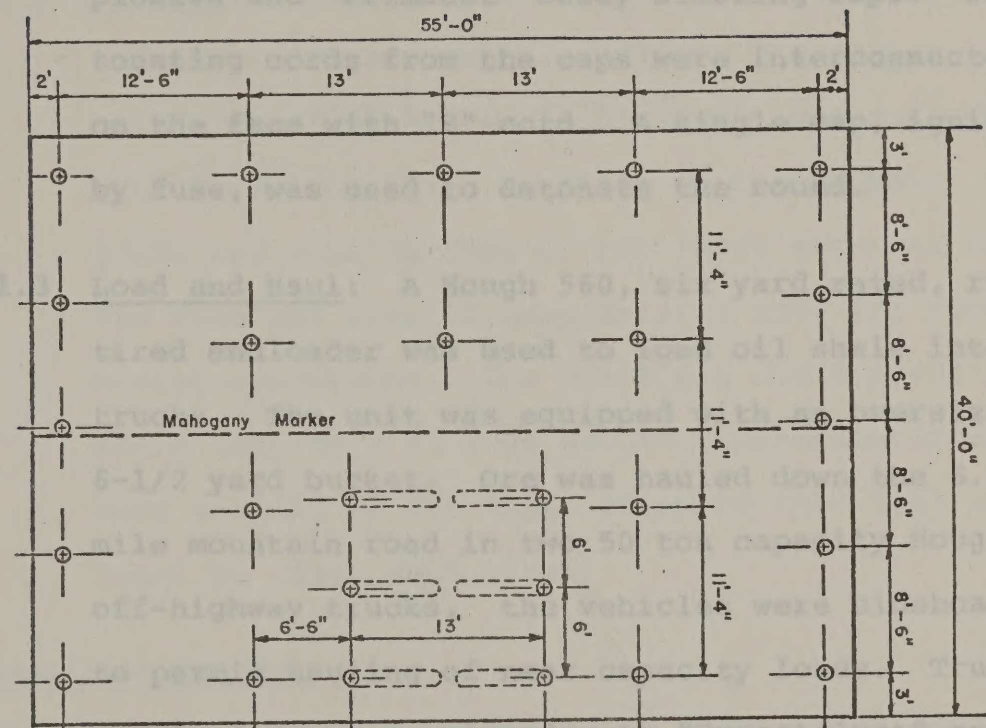

Figure 3-1

Typical 26 Hole Pattern
Anvil Points Mine

hole. The effect was twofold. Both the reduced amount of explosive and the air cushion around the explosive column tended to reduce blast damage to the pillars.

All blastholes were primed with a high strength explosive and "Primadet" delay blasting caps. Detonating cords from the caps were interconnected on the face with "E" cord. A single cap, ignited by fuse, was used to detonate the round.

3.1.3 Load and Haul: A Hough 560, six yard rated, rubber tired endloader was used to load oil shale into trucks. The unit was equipped with an oversized 6-1/2 yard bucket. Ore was hauled down the 5.2 mile mountain road in two 50 ton capacity Hough 350, off-highway trucks, the vehicles were sideboarded to permit hauling of near capacity loads. Trucks and loader were equipped with "Oxycatalyst" exhaust conditioners to permit operation within the mine.

3.1.4 Roof Bolting: The mine roof was roof bolted as it was exposed. Bolts, six and seven feet in length, were installed in a grid pattern on approximate five foot centers after each round was mucked out. Bolts were torqued to approximately 150 foot-pounds

as they were installed. Roof bolting was accomplished from an elevating platform equipped with a single Gardner-Denver D93HR drill machine. This hydraulically rotated drill was used to drill bolt holes and tighten the roof bolts.

3.1.5 Scaling: Rib and face scaling was accomplished with a Gradall 600 mechanical scaler. The scaler, actually a modified hydraulic backhoe, was equipped with a scaling tooth in place of the bucket. The tooth was used to rake or pry loose material from the face and ribs to make an area safe for subsequent mining operations. The G-600 rig could reach and scale only to a 37 foot height, consequently some hand scaling of the upper three or four feet was required after each blast.

3.2 Production Statistics

The first round taken from the Anvil Points mine during the Paraho Project was blasted August 7, 1974. The final heading was shot on November 26, 1975. In all, 38 full rounds were shot in the campaign, advancing headings and crosscuts a total of 692 feet. Other statistics are as follows:

- Total mined — 101,490 tons
- Advance per round — 18.2 Feet

o	Production per round	2,670 Tons
o	Explosives factor*	0.85 Pounds/Ton
o	Bit life**	327 Feet/Bit

* Explosives factor adversely affected by particle size limitation set by plant's primary crusher.

** Bit life adversely affected by use of 24 substandard bits.

4. INDUSTRIAL ENGINEERING

5. APPENDIX

4. INDUSTRIAL ENGINEERING

4.1 Man/Machine Work Studies

Productivity and cycle times for the various mining functions in a commercial sized operation were developed from data obtained from time studies of the Anvil Points mine operation. Each function was studied with the objective of developing data that met 95% statistical confidence limits. This data, which was based on the prototype equipment, was used in the development of productivity and cycle times for the equipment envisioned for a commercial sized operation. Standard industrial and mining engineering techniques were used in the analyses of the data.

The specific functions studies were drilling, charging and blasting, loading, hauling, roof bolting, scaling, and ventilation.

4.2 Equipment Testing

4.2.1 Drilling: During the mining program at Anvil Points, several drill manufacturers were offered an opportunity to test their equipment in oil shale. It was desired to investigate fully all potential oil shale drill candidates. Garner-Denver, Ingersoll-Rand, and Joy responded. Straight rotary, rotary-

percussion and percussion drill actions were subsequently investigated.

Reports of the drilling tests have been published. Results can be generally summarized as follows:

- o Rotary drill action is preferred for drilling the richer oil shales. However, in lean shale (-20 gpt) rotary drill penetration rates are unacceptably low. Other types of drilling should be considered if lean shale is to be mined.

- o Rotary-percussion drill action is a potential means of drilling oil shale providing bits of proper design can be obtained. In contrast to straight rotary drill action, this type of drilling resulted in faster bit penetration in the lean shale than in the richer kerogen bearing rock.

- o Percussion drilling, using large compressed air operated drills, appears to be competitive with other types of drilling actions. In addition, a longer bit life appears likely with this type of equipment. The primary disadvantage in use of percussion

drills is the requirement of large volumes of compressed air.

4.2.2 Scaling: A Drott-Cruz-Air, Model 40YR, rubber tired, hydraulic backhoe, equipped with a single ripper tooth in place of the conventional bucket, was tested for its ability to serve as a mechanical scaler. The machine performed well and will warrant consideration when equipping a commercial oil shale mine.

5. APPENDIX

5. APPENDIX

The following reports prepared by The Cleveland-Cliffs Iron Company for the Paraho Oil Shale Demonstration are included herein:

5.1 Gardner-Denver Drill and Bit Test

5.2 Gardner-Denver All Hydraulic Rotary Percussion Drill Test

5.3 Ingersoll-Rand Rotary-Percussion Drill Tests

5.4 Joy Drill and Bit Test

5.5 Man/Machine Work Studies

- 5.5.1 Face Drilling
- 5.5.2 Charging and Blasting
- 5.5.3 Scaling
- 5.5.4 Roof Bolting
- 5.5.5 Ventilation
- 5.5.6 Truck Loading and Hauling

PARAHO DEMONSTRATION PROJECT

GARDNER-DENVER DRILL & BIT TEST REPORT

FEBRUARY 1976

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INTRODUCTION

These Gardner-Denver drill and bit tests were conducted at the Paraho Demonstration Project's Anvil Points mine near Rifle, Colorado. The tests were accomplished in three phases, one with a Gardner-Denver bench rig equipped with a 63 RPM drill motor using rotary and rotary percussion (a Mission Megadrill down the hole hammer) type drilling; two, using the bench rig equipped with a 145 RPM drill motor with straight rotary drilling; and three, using the mine's Gardner-Denver jumbo equipped with a J.E.D.-1 drill with hard (110 RPM) and soft (170 RPM) rotary speeds. Straight rotary drilling was used in this phase of the test. Results of the three phases are recorded in the following sections.

Gardner-Denver Company sustained the majority of the cost of drilling equipment and supplies used in these tests.

PHASE ONE

The first phase test involved the testing of various bit types in order to determine which bit type performed best in the drilling of oil shale. Also, a down-the-hole hammer was tested with the above bits.

The down-the-hole hammer was a T.R.W. Mission Megadrill which produced 1,200 blows per minute at approximately 100 foot pounds per blow.

Both horizontal and vertical holes were drilled during this phase. Horizontal holes were drilled within three to four feet on each side of the Mahogany marker while the vertical holes were collared in the floor 20 feet below the Mahogany marker. The vertical holes were drilled in medium and high grade shale. The horizontal holes were drilled in low grade shale.

Bits tested in this phase included Ken Claw bits made by Kenrock Bit Company, four wing drag bits made by Kay Bit Company and Gault Tool Company and some special made bits from Kay Bit Company. One tri-cone roller bit, made by Barrel, was also tested. A hole-by-hole breakdown on this section is included on pages 3 to 10. Figure 1, page 42, is a sketch of a four wing drag bit.

PHASE ONE RESULTS

Gardner-Denver Bench Rig with 63 RPM drill motor - rotary and rotary percussion drilling. All pressures are hydraulic gauge pressures in pounds per square inch. The booster is hydraulic fluid flow in gallons per minute.

Ken Claw Bits (Point Contact Bits):

1. Bit - 4-3/4" four-toothed ripper with five button pilot starter

   Vertical hole (straight rotary)

   Collar -

   Drill - 8 feet in 7.00 minutes - 1.14 feet/minute

   Pressures (psi):
   Rotation - 900
   Down - 700

   Booster - 36 gallons/minute

2. Bit - 4-3/4" four-toothed ripper with five button pilot starter

   Vertical hole (straight rotary)

   Collar -

   Drill - 20 feet in 13.5 minutes - 1.48 feet/minute

   Pressures (psi):
   Rotation - 1,000
   Down - 1,000

   Booster - 38 gallons/minute

3. Bit - 4-3/4" four-toothed ripper with five button pilot starter

   Vertical hole (straight rotary)

   Collar -

   Drill - 9 feet in 5.0 minutes - 1.80 feet/minute

   Pressures (psi):
   Rotation - 1,000
   Down - 1,500 (bit bound)

   Booster - 38 gallons/minute

<u>PHASE ONE RESULTS</u>

Gardner-Denver Bench Rig with 63 RPM drill motor - rotary and rotary percussion drilling. All pressures are hydraulic gauge pressures in pounds per square inch. The booster is hydraulic fluid flow in gallons per minute.

<u>Ken Claw Bits (Point Contact Bits):</u>

1. Bit - 4-3/4" four-toothed ripper with five button pilot starter

   Vertical hole (straight rotary)

   Collar -

   Drill - 8 feet in 7.00 minutes - 1.14 feet/minute

   Pressures (psi):
   Rotation - 900
   Down - 700

   Booster - 36 gallons/minute

2. Bit - 4-3/4" four-toothed ripper with five button pilot starter

   Vertical hole (straight rotary)

   Collar -

   Drill - 20 feet in 13.5 minutes - 1.48 feet/minute

   Pressures (psi):
   Rotation - 1,000
   Down - 1,000

   Booster - 38 gallons/minute

3. Bit - 4-3/4" four-toothed ripper with five button pilot starter

   Vertical hole (straight rotary)

   Collar -

   Drill - 9 feet in 5.0 minutes - 1.80 feet/minute

   Pressures (psi):
   Rotation - 1,000
   Down - 1,300 (bit bound)

   Booster - 38 gallons/minute

Ken Claw Bits (Point Contact Bits) (Continued):

4. Bit - 4-3/4" four-toothed ripper with five button pilot starter

Horizontal hole (straight rotary)

Collar -

Drill - 20 feet in 20.87 minutes - 0.96 feet/minute

Pressures (psi):
Rotation - 1,000
Down - 1,300

5. Bit - 4-3/4" five-toothed ripper 'Mini-Mite"

Vertical hole (straight rotary)

Collar -

Drill - 12 feet in 12.14 minutes - 0.99 feet/minute

Pressures (psi):
Rotation - 800
Down - 1,000

Booster - 36 gallons/minute

6. Bit - 4-3/4" five-toothed ripper 'Mini-Mite"

Horizontal hole (straight rotary) 10 feet below Mahogany marker

Collar -

Drill - 8 feet in 11.0 minutes - .72 feet/minute

Pressures (psi):
Rotation - 750
Down - 1,000

Booster - 36 gallons/minute

7. Bit - 4-3/4" five-toothed ripper 'Mini-Mite"

Vertical hole (straight rotary)

Collar - .62

Drill - 20.7 feet in 19.4 minutes - 1.06 feet/minute

Pressures (psi):
Rotation - 1,000
Down - 1,200

Booster - 38 gallons/minute

Ken Claw Bits (Point Contact Bits) (Continued):

8. Bit - 4-3/4" four-toothed ripper

Vertical hole with rotary percussion hammer

Collar - 1.00 minute

Drill - 23.34 feet in 6.91 minutes - 3.37 feet/minute

Pressures (psi):
Rotation - 1,300
Down - 1,000

Booster - 38 gallons/minute

Kay & Gault Bits:

9. Bit - 4-1/4" Kay rotary-percussion bit

Vertical hole with rotary percussion hammer

Collar -

Drill - 23.34 feet in 15.65 minutes - 1.49 feet/minute

Pressures (psi):
Rotation - 700
Down - 320

Booster - 36 gallons/minute

10. Bit - 4-1/4" Kay resharpened drag bit

Vertical hole (straight rotary)

Collar -

Drill - 20.7 feet in 9.41 minutes - 2.20 feet/minute

Pressures (psi):
Rotation - 950
Down - 1,600

Booster - 38 gallons/minute

Kay & Gault Bits (Continued):

11. Bit - 4-1/4" Kay resharpened drag bit (same as #10)

    Vertical hole with rotary percussion hammer

    Collar -

    Drill - 23.34 feet in 6.78 minutes - 3.44 feet/minute

    Pressures (psi):
    Rotation - 1,000
    Down - 1,400

    Booster - 38 gallons/minute

12. Bit - 4-1/4" Gault resharpened drag bit

    Vertical hole with rotary percussion hammer

    Collar -

    Drill - 23.34 feet in 5.01 minutes - 4.66 feet/minute

    Pressures (psi):
    Rotation - 1,200
    Down - 1,400

    Booster - 38 gallons/minute

13. Bit - 4-1/4" Kay special drag bit

    Vertical hole (straight rotary)

    Collar -

    Drill - 20.7 feet in 8.5 minutes - 2.43 feet/minute

    Pressures (psi):
    Rotation - 900
    Down - 1,400

    Booster - 36 gallons/minute

14. Bit - 4-1/4" Kay special drag bit

    Vertical hole with rotary percussion hammer

    Collar - .24

    Drill - 23.34 feet in 5.43 minutes - 4.29 feet/minute
    (Tore all four carbides from seatings)

    Pressures (psi):
    Rotation - 1,200-1,300
    Down - 1,400

    Booster - 38 gallons/minute

Kay & Gault Bits (Continued):

15. Bit - 4-1/4" Gault resharpened bit with two broken carbides

Vertical hole with rotary percussion hammer
(This bit attained 4.66 feet/minute on a previously drilled hole)

Collar - .46

Drill - 23.34 feet in 7.69 minutes - 3.03 feet/minute

Pressures (psi):
Rotation - 1,000
Down - 1,400

Booster - 38 gallons/minute

16. Bit - 4-1/4" Gault resharpened bit (same bit as #15)

Vertical hole with rotary percussion hammer

Collar -

Drill - 23.34 feet in 10.04 minutes - 2.32 feet/minute
(Tore the remaining two carbide inserts from their seatings)

Pressures (psi):
Rotation - No Recordings
Down - No Recordings

Booster - 36 gallons/minute

17. Bit - 4-1/4" Barrel Tri-Cone Roller Bit

Vertical hole with rotary percussion hammer

Collar -

Drill - 23.34 feet in 17.28 minutes - 1.35 feet/minute

Pressures (psi):
Rotation - 900
Down - 1,200

Booster - 38 gallons/minute

18. Bit - 4-1/4" Tri-Cone Roller Bit (same bit as #17)

Vertical hole (straight rotary)

Collar -

Drill - 1.5 feet in 2 minutes - .75 feet/minute

Pressures (psi):
Rotation - 800
Down - 1,400

Booster - 36 gallons/minute

Kay & Gault Bits (Continued):

19. Bit - 4-1/4" Tri-Cone roller bit (same bit as #17-#18)

Vertical hole with rotary percussion hammer

Collar -

Drill - 22 feet in 17.15 minutes - 1.28 feet/minute
(bit destroyed - one roller tore out)

Pressures (psi):
Rotation - 900
Down - 1,400

Booster - 38 gallons/minute

The following horizontal holes were drilled in hard zones above and below the Mahogany marker.

20. Bit - 4-1/4" Gault resharpened bit

3.5 feet above Mahogany marker with rotary percussion hammer

Collar - .26

Drill - 23.34 feet in 9.34 minutes - 2.49 feet/minute
(tore three carbide inserts from seatings and chipped the fourth)

Pressures (psi):
Rotation - 900
Down - 1,000

Booster - 38 gallons/minute

21. Bit - 4-1/4" Kay Button "P" bit

3.0 feet above Mahogany Marker with rotary percussion hammer

Collar - .26

Drill - 23.34 feet in 18.06 minutes - 1.29 feet/minute

Pressures (psi):
Rotation - 900
Down - 500

Booster - 41 gallons/minute

The following horizontal holes were drilled in hard zones above and below the Mahogany marker.

Kay & Gault Bits (Continued):

22. Bit - 4-1/4" Kay rotary percussion bit

2.5 feet above Mahogany marker with rotary percussion hammer

Collar - .88

Drill - 23.34 feet in 21.24 minutes - 1.09 feet/minute

Pressures (psi):
Rotation - 850
Down - 500

Booster - 41 gallons/minute

23. Bit - 4-1/4" Kay resharpened drag bit

Drilled in Mahogany marker with rotary percussion hammer

Collar -

Drill - 5 feet in 3.86 minutes - 1.29 feet/minute
(bit completely destroyed)

Pressures (psi):
Rotation - 850
Down - 1,000

Booster - 41 gallons/minute

24. Bit - 4-1/4" Kay Button "P" bit

.5 feet above Mahogany marker with rotary percussion hammer

Collar -

Drill - 23.34 feet in 18.35 minutes - 1.27 feet/minute

Pressures (psi):
Rotation - 750
Down - 500

Booster - 36 gallons/minute

Kay & Gault Bits (Continued):

25. Bit - 4-1/4" Kay rotary percussion bit

2.2 feet above Mahogany marker with rotary percussion hammer

Collar - .48

Drill - 23.34 feet in 18.03 minutes - 1.30 feet/minute

Pressures (psi):
Rotation - 850
Down - 500

Booster - 41 gallons/minute

SUMMARY:

Results from this test indicated that four wing drag bits performed best with straight rotary drilling. When used with rotary percussion drilling they attained good penetration rates but did not hold up well. Most drag bits were destroyed when the carbide inserts were torn from their seatings, usually during rotary percussion drilling.

The Ken Claw (point contact) bits, made by Kenrock Bit Company did not perform well with either rotary or rotary percussion drilling. The special bits, one a rotary percussion type bit and the other a button type bit, made by Kay Bit Company, did not perform as well as expected. Cutting and clearance angles on the rotary percussion bit were not applicable to the drilling of oil shale. This was the first rotary percussion bit tried. The cutting and clearance angles were not applicable to the drilling of oil shale as there was no bit sharpening equipment for experimentation with different angles.

The tri-cone roller bit, made by Barrel, was destroyed when one roller was torn from its mounting. This was during rotary percussion drilling. Penetration rates with this bit were less than 1.5 feet per minute.

In conclusion, it was substantiated that drag bits work best in rotary drilling of oil shale. With regard to rotary percussion drilling of oil shale, it was substantiated that drag bits would not hold up under the percussion impact. In testing for a bit that will satisfactorily drill oil shale with rotary percussion drilling, it is suggested that percussion and rotary percussion type bits be tested. Also, these bits should be sharpened to various angles in an attempt to find optimum angles for drilling oil shale.

PHASE TWO

The second phase of this test deals with various four wing drag bits with different clearance and rake angles in an attempt to determine optimum angles with respect to penetration rates. Also, an attempt was made to substantiate that precision bit sharpening is necessary for attaining good penetration rates and the longest possible bit life. The bits in this section were recorded by their carbide hardness and by an angle in degrees. This angle is the clearance angle measured from vertical minus the rake angle (example 1-8 -22°). Figure 1 on page 42 shows a typical four wing drag bit. The bits used in this phase of the test were all Kay and Gault four wing drag type bits furnished, at no cost, by Gardner-Denver Company.

A 145 rpm drill motor was used on a Gardner-Denver bench rig for this test. A hole-by-hole breakdown on this section is included on pages 13 to 26. Most bits were recorded by the degree of the angles on that particular bit. The first 15 holes were drilled with the booster compressor connected, the remaining 35 holes were drilled with the booster compressor disconnected. The booster was disconnected to better distribute the hydraulic power to the remaining active systems. Cleaning of the hole became a problem while the booster compressor was disconnected.

All holes drilled in this phase of the test were vertical. They were collared some 20 feet below the Mahogany marker and were drilled through both medium and high grade shale.

PHASE TWO RESULTS

Gardner-Denver Bench Rig with 145 RPM drill motor - rotary drilling with and without a booster compressor (vertical holes)

Two (2) holes drilled with the mine jumbo - horizontal holes:

#4 Carbide:

10 feet above the Mahogany marker (black seam)

Collar the hole - .32

Drill the hole - 25 feet in 3.82 minutes - 6.8 feet/minute

Retract drill - .88

Pressures (psi):
Drill - 1,400
Down (Feed) - 900

#8 Carbide:

Top hole (hard drilling) 15 feet above Mahogany marker

Collar the hole - .35

Drill the hole - 26 feet in 5.83 minutes - 4.4 feet/minute

Retract drill - 1.11

Pressures (psi):
Drill - 1,450 (end of hole 1,100)
Feed - 1,000

All holes drilled to a depth of 18 feet. The pressures are hydraulic gauge pressures in pounds per square inch. The booster is hydraulic fluid flow in gallons per minute.

1. #4 Standard Carbide:

   Collar - .09

   Drill - 3.68 minutes - 4.89 feet/minute

   Pressures (psi):
   Rotation - 1,450
   Down - 1,200

   Booster - 38 gallons/minute

2. #4 Standard Carbide:

   Collar - .15

   Drill - 4.02 minutes - 4.47 feet/minute

   Pressures (psi):
   Rotation - 1,250 - 1,500*
   Down - 700

   Booster - 41 gallons/minute

3. #8 Standard Carbide:

   Collar - .18

   Drill - 3.59 minutes - 5.01 feet/minute

   Pressures (psi):
   Rotation - 1,000 - 1,500*
   Down - 700

   Booster - 41 gallons/minute

4. #8 Standard Carbide:

   Collar -

   Drill - 3.62 minutes - 4.97 feet/minute

   Pressures (psi):
   Rotation - 1,000 - 1,500*
   Down - 700

   Booster - 41 gallons/minute

* Varies due to hardness of rock being drilled.

5. #8 Standard Carbide:

Collar - .19

Drill - 3.98 minutes - 4.52 feet/minute

Pressures (psi):
Rotation - 1,000 - 1,500*
Down - 700

Booster - 41 gallons/minute

6. Gault Reground (relieved):

Collar -

Drill - 3.08 minutes - 5.84 feet/minute

Pressures (psi):
Rotation - 1,000 - 1,500*
Down - 700

Booster - 42 gallons/minute

7. Gault Reground (NOT relieved):

Collar - .10

Drill - 3.70 minutes - 4.86 feet/minute

Pressures (psi):
Rotation - 1,000 - 1,500*
Down - 700

Booster - 41 gallons/minute

8. 1-8 - 22°:

Collar - .20

Drill - 2.94 minutes - 6.12 feet/minute

Pressures (psi):
Rotation - 1,000 - 1,500*
Down - 700

Booster - 41 gallons/minute

* Varies due to hardness of rock being drilled.

9. 1-4 - 28^{o}:

Collar - .35

Drill - 4.49 minutes - 4.00 feet/minute

Pressures (psi):
Rotation - 1,000 - 1,500*
Down - 700

Booster - 41 gallons/minute

10. 2-4 - 25^{o}:

Collar - .08

Drill - 3.81 minutes - 4.72 feet/minute

Pressures (psi):
Rotation - 1,000 - 1,500*
Down - 700

Booster - 41 gallons/minute

11. 2-8 - 24^{o}:

Collar - .09

Drill - 3.06 minutes - 5.88 feet/minute

Pressures (psi):
Rotation - 1,000 - 1,500*
Down - 700

Booster - 41 gallons/minute

12. 3-4 - 18^{o}:

Collar -

Drill - 2.98 minutes - 6.04 feet/minute

Pressures (psi):
Rotation - 1,000 - 1,500*
Down - 700

Booster - 41 gallons/minute

* Varies due to the hardness of rock being drilled.

13. 3-8 - 18°:

Collar - .19

Drill - 3.03 minutes - 5.94 feet/minute

Pressures (psi):
Rotation - 1,000 - 1,500*
Down - 700

Booster - 41 gallons/minute

14. Old Kay (resharpened):

Collar - .10

Drill - 6.54 minutes - 2.18 feet/minute

Pressures (psi):
Rotation - 1,000 - 1,500
Down - 700

Booster - 41 gallons/minute

15. Gault (relieved) Reground:

Collar - .10

Drill - 3.30 minutes - 5.45 feet/minute

Pressures (psi):
Rotation - 1,000 - 1,500*
Down - 700

Booster - 41 gallons/minute

* Varies due to the hardness of rock being drilled.

All holes vertical - rotation (145 RPM). Booster compressor disconnected. The compressor pressure is the hydraulic system pressure in pounds per square inch.

1. 1-8 - 22°:

Collar -

Drill - 2.85 minutes - 6.31 feet/minute

Pressures (psi):
Rotation - 1,250 - 1,500* (drilled dry)
Down - 800

Compressor - 3,800

2. 1-8 - 22°:

Collar - .08

Drill - 3.05 minutes - 5.90 feet/minute

Pressures (psi):
Rotation - 1,000 to 1,500* (drilled wet)
Down - 800

Compressor - 4,200

3. 1-8 - 22°:

Collar - .10

Drill - 3.80 minutes - 4.73 feet/minute

Presssures (psi):
Rotation - 1,200 - 1,700*
Down - 900 (bit dulling and binding)

Compressor - 4,000

4. 1-8 - 22°:

Collar - .11

Drill - 3.87 minutes - 4.65 feet/minute

Pressures (psi):
Rotation - 1,300 - 1,700*
Down - 1,000

Compressor - 4,200

* Varies due to hardness of rock being drilled.

5. 2-8 - 24°:

Collar - .09

Drill - 4.12 minutes - 4.37 feet/minute

Pressures (psi):
Rotation - 1,100 - 1,600
Down - 800

Compressor - 4,000

6. 2-8 - 24°:

Collar - .10

Drill - 4.23 minutes - 4.25 feet/minute

Pressures (psi):
Rotation - 1,200 - 1,600
Down - 900 (bit binding)

Compressor - 4,200

7. 2-8 - 24°:

Collar - .09

Drill - 4.08 minutes - 4.41 feet/minute

Pressures (psi):
Rotation - 1,200 - 1,600* (bit binding)
Down - 1,000

Compressor - 4,200

8. 2-4 - 25°:

Collar - .10

Drill - 4.33 minutes - 4.15 feet/minute

Pressures (psi):
Rotation - 1,200 - 1,700*
Down 800

Compressor - 4,000

* Varies due to the hardness of rock being drilled.

9. 2-4 - 25°:

Collar - .08

Drill - 4.10 minutes - 4.39 feet/minute

Pressures (psi):
Rotation - 1,200 - 1,800
Down - 900

Compressor - 4,200

10. 2-4 - 25°:

Collar - .09

Drill - 4.00 minutes - 4.50 feet/minute

Pressures (psi):
Rotation - 1,200 - 1,700*
Down - 1,000

Compressor - 3,300

11. 3-4 - 18°:

Collar - .11

Drill - 3.30 minutes - 5.45 feet/minute

Pressures (psi):
Rotation - 1,200 - 1,600*
Down - 800

Compressor - 4,200

12. 3-4 - 18°:

Collar - .08

Drill - 3.30 minutes - 5.45 feet/minute

Pressures (psi):
Rotation - 1,100 - 1,600*
Down - 900

Compressor - 3,800

* Varies due to the hardness of rock being drilled.

13. 3-4 - 18°:

Collar - .12

Drill - 3.55 minutes - 5.07 feet/minute

Pressures (psi):
Rotation - 1,300 - 1,800*
Down - 1,000 (bit binding)

Compressor - 3,800

14. 3-8 - 18°:

Collar - .10

Drill - 3.01 minutes - 5.98 feet/minute

Pressures (psi):
Rotation - 1,200 - 1,700*
Down - 800

Compressor - 4,100

15. 3-8 - 18°:

Collar - .08

Drill - 3.24 minutes - 5.55 feet/minute

Pressures (psi):
Rotation - 1,300 - 1,800*
Down - 900

Compressor - 4,000

16. 3-8 - 18°:

Collar - .09

Drill - 2.99 minutes - 6.02 feet/minute

Pressures (psi):
Rotation - 1,300 - 1,800*
Down - 1,000 (bit binding)

Compressor - 3,800

* Varies due to hardness of rock being drilled.

17. New 8 - Anvil Points Grind:

Collar -

Drill - 4.88 minutes - 3.68 feet/minute

Pressures (psi):
Rotation - 1,200 - 1,300*
Down - 700

Compressor - 3,300

18. New 8 - Anvil Points Grind:

Collar - .08

Drill - 5.91 minutes - 3.04 feet/minute

Pressures (psi):
Rotation - 1,200 - 1,600*
Down - 800

Compressor - 3,500

19. Resharpened Gault Anvil Points Grind:

Collar - .11

Drill - 3.80 minutes - 4.73 feet/minute

Pressures (psi):
Rotation - 1,000 - 1,500*
Down 700

Compressor - 3,600

20. Resharpened Gault Anvil Points Grind:

Collar - .09

Drill - 3.62 minutes - 4.97 feet/minute

Pressures (psi):
Rotation - 1,000 - 1,500*
Down - 800

Compressor - 3,900

* Varies due to the hardness of rock being drilled.

21. Resharpened Gault Bit Anvil Points Grind:

Collar - .10

Drill - 3.35 minutes - 5.37 feet/minute

Pressures (psi):
Rotation - 1,200 - 1,600*
Down - 900

Compressor - 3,900

22. Resharpened Gault Anvil Points Grind:

Collar - .11

Drill - 3.70 minutes - 4.86 feet/minute

Pressures (psi):
Rotation - 1,200 - 1,600
Down - 1,000

Compressor - 4,100

23. Resharpened Gault (cracked insert):

Collar -

Drill - 3.80 minutes - 4.74 feet/minute

Pressures (psi):
Rotation - 1,000 - 1,500*
Down - 700

Compressor - 4,200

24. 1-8 Standard:

Collar - .09

Drill - 4.36 minutes - 4.13 feet/minute

Pressures (psi):
Rotation - 1,100 - 1,700*
Down - 900

Compressor - 4,200

* Varies due to the hardness of rock being drilled.

25. 1-8 Standard:

Collar - .09

Drill - 3.75 minutes - 4.80 feet/minute

Pressures (psi):
Rotation - 1,250 - 1,750*
Down - 1,100

Compressor - 3,900

26. 1-8 Standard:

Collar -

Drill - 4.31 minutes - 4.17 feet/minute (bit binding)

Pressures (psi):
Rotation - 1,250 - 1,750*
Down - 1,300

Compressor - 3,500

27. 1-8 Standard:

Collar - .08

Drill - 4.18 minutes - 4.30 feet/minute (bit binding)

Pressures (psi):
Rotation - 1,200 - 1,600*
Down - 1,200

Compressor - 3,600

28. 1-8 Standard:

Collar -

Drill - 4.08 minutes - 4.41 feet/minute

Pressures (psi):
Rotation - 1,100 - 1,600*
Down - 900

Compressor

* Varies due to the hardness of rock being drilled.

29. 1-8 Standard:

Collar - .10

Drill - 4.11 minutes - 4.38 feet/minute

Pressures (psi):
Rotation - 1,100 - 1,600*
Down - 1,000

Compressor - 3,900

30. 1-4 Standard:

Collar - .09

Drill - 4.55 minutes - 3.95 feet/minute (bit binding)

Pressures (psi):
Rotation - 1,100 - 1,500*
Down - 900

Compressor - 4,100

31. 1-4 Standard:

Collar - .07

Drill - 4.59 minutes - 3.92 feet/minute

Pressures (psi):
Rotation - 1,100 - 1,600*
Down - 1,000

Compressor - 3,700

32. 1-4 Standard:

Collar - .11

Drill - 4.60 minutes - 3.91 feet/minute

Pressures (psi):
Rotation - 1,100 - 1,600*
Down - 800

Compressor - 3,700

* Varies due to the hardness of rock being drilled.

33. 1-4 Standard:

Collar - .09

Drill - 5.63 minutes - 3.19 feet/minute

Pressures (psi):
Rotation - 1,000 - 1,500*
Down - 700

Compressor - 3,600

34. 1-4 - 28°:

Collar - .08

Drill - 4.25 minutes - 4.23 feet/minute

Pressures (psi):
Rotation - 1,000 - 1,500*
Down - 900

Compressor - 4,200

35. 1-4 - 28°:

Collar - .14

Drill - 8.35 minutes - 2.15 feet/minute

Pressures (psi):
Rotation - 1,300 - 1,750*
Down - 1,000

Compressor - 3,800

* Varies due to the hardness of the rock being drilled.

SUMMARY:

The second phase of this test dealt with the testing of various drag bits with different clearance and rake angles. These bits were precision sharpened in an attempt to substantiate that precision bit sharpening is necessary for maintaining good penetration rates with the longest possible bit life.

Results from the first 14 holes drilled in this phase indicate that good penetration rates can be attained at a relatively low feed pressure (700 psi); see drill hole information sheets, pages 13 to 26 and Table I, page 28. Each bit was tested at various feed pressures in an attempt to determine an optimum feed pressure for attaining maximum penetration rates. Results are found on the drill hole information sheets, pages 13 to 26 and Table II, page 29. The optimum feed pressure (best penetration rate) varied for each bit. Testing indicated that the clearance angle of each bit governs the feed pressure needed to attain the best penetration rates. On page 42, Figure 1 is a drawing of a typical drag bit.

Variation of feed pressure with some bits did not make a significant difference in penetration rates. These bits had about the same penetration rates with 700 psi as with 1,000 psi. This pressure is hydraulic gauge pressure in pounds per square inch.

TABLE I

PHASE TWO - COMPARISON OF FEED PRESSURE (psi) AND PENETRATION RATES (feet/minute) WITH THE BOOSTER COMPRESSOR CONNECTED

BIT	FEED PRESSURE* (Psi)	PENETRATION RATE (feet/minute)
#4 Standard	700	4.47
#8 Standard	700	5.01
#8 Standard	700	4.97
#8 Standard	700	4.52
Gault Reground (Relieved)	700	5.84
Gault Reground (Not Relieved)	700	4.86
1-8 - 22°	700	6.12
1-4 - 28°	700	4.00
2-4 - 25°	700	4.72
2-8 - 25°	700	5.88
3-4 - 18°	700	6.04
3-8 - 18°	700	5.94
Kay Resharpened	700	2.18
Gault Resharpened (Relieved)	700	5.45

* First 14 holes were drilled at a constant feed pressure to determine which bit performed best at this pressure.

TABLE II

PHASE TWO - COMPARISON OF FEED PRESSURE (psi) AND PENETRATION RATES (feet/minute) WITH THE BOOSTER COMPRESSOR DISCONNECTED

BIT	FEED PRESSURE (psi)	PENETRATION RATES (feet/minute)
1-8 - 22°	800	6.31 (Dry)
	800	5.90 (Wet)
	900	4.73
	1,000	4.65
2-8 - 24°	800	4.37
	900	4.25
	1,000	4.41
2-4 - 25°	800	4.15
	900	4.39
	1,000	4.50
3-4 - 18°	800	5.45
	900	5.45
	1,000	5.07
3-8 - 18°	800	5.98
	900	5.55
	1,000	6.02
New Standard 8 (Anvil Points Grind*)	700	3.68
	800	3.04
Gault (Resharpened)	700	4.73
	800	4.97
	900	5.37
	1,000	4.86
Gault (Resharpened-cracked insert)	700	4.74
1-8 Standard	900	4.13
	1,100	4.80
	1,300	4.17
	1,200	4.30
	900	4.41
	1,000	4.38
1-4 Standard	900	3.95
	1,000	3.92
	800	3.91
	700	3.19
1-4 - 28°	900	4.23
	1,000	2.15

* Resharpened on Mine bit sharpener.

PHASE THREE

The third phase of this test encompassed the use of the face jumbo and the bits used in Phase Two at the Anvil Points mine. These bits had been precision resharpened to their approximate original angles. Bits in this section were recorded by their carbide hardness and two angles in degrees. The first of these angles represents the clearance angle measured from vertical and the second represents the clearance angle measured from vertical minus the rake angle (example 1-8 -32° -26°). Figure 1 on page 42 shows a typical four wing drag bit. Horizontal rotary drilling was done on a 23 hole round designed for a commercial size oil shale mining operation. These holes were drilled to a depth of 22 feet. The face cross section indicates that the face is approximately half high grade and half low grade, each with different drilling characteristics.

The high grade material is relatively soft, resilient and highly susceptible to rotary drilling. The best penetration rates are attained in this material. The low grade material is hard and not as susceptible to rotary drilling as the high grade material. Rotary drilling in this material is difficult with poor penetration rates as well as poor bit life. This split face condition makes consistent drilling extremely difficult.

A hole-by-hole breakdown on bit performance can be found on pages 31 through 36. Also included on pages 37 through 39 are horsepower requirements based on actual hydraulic pressure recordings.

Gardner-Denver drill and bit test - horizontal rotary drilling using Gardner-Denver drill jumbo with J.E.D. 1 rotary drill. The rotation and feed pressures are hydraulic gauge pressures in pounds per square inch.

Rotation:
Hard - 110
Soft - 170

Hole Depth: All holes were 22 feet except cut holes which were 24 feet.

1. 1-8 - 32° - 26°

+15 feet Mm* (hard)

Collar - .36

Drill - 8.70 minutes - 2.5 feet/minute (chipped carbides on bit)

Pressures (psi):
Rotation - 1,250
Feed - 900 - 1,000
Air - 82

2. 1-4 - 32° - 26°

+4 feet Mm* (hard)

Collar - .28

Drill - 6.71 minutes - 3.2 feet/minute.

Pressures (psi):
Rotation - 1,100
Feed - 1,000 - 1,200
Air - 86

3. 2-8 - 30° - 22°

+15 feet Mm* (hard)

Collar - .30

Drill - 8.35 minutes - 2.6 feet/minute.

Pressures (psi):
Rotation - 1,200
Feed - 1,000 - 1,200
Air - 82

* Mm = Mahogany marker.

4. 2-8 - 30° - 22°

+4 feet Mm* (hard)

Collar - .26

Drill - 6.20 minutes - 3.5 feet/minute

Pressures (psi):
Rotation - 1,000 - 1,200
Feed - 900 - 1,000
Air 84

5. 2-4 - 30° - 24°

-6 feet Mm* (soft)

Collar - .32

Drill - 3.46 minutes - 6.35 feet/minute

Pressures (psi):
Rotation - 1,000 - 1,400
Feed - 1,000 - 1,100
Air 90

6. 2-4 - 30° - 24°

-14 feet Mm* (soft)

Collar - .21

Drill - 4.50 minutes - 4.9 feet/minute (chipped carbide)

Pressures (psi):
Rotation - 1,000 - 1,400
Feed 800
Air 84

7. 2-4 - 30° - 24°

-6 feet Mm* (soft seam)

Collar - .23

Drill - 4.65 minutes - 4.7 feet/minute

Pressures (psi):
Rotation - 1,000 - 1,250
Feed - 1,000
Air - 90

* Mm = Mahogany marker.

8. 2-4 - 30° - 24°

-8 feet Mm* (cut hole)

Collar -

Drill - 24 feet - 5.82 minutes - 4.1 feet/minute (chipped second carbide)

Pressures (psi):
Rotation - 1,000 - 1,200
Feed - 800
Air - 88

9. 3-8 - 22° - 15°

+2.5 feet Mm* (hard) (cut hole)

Collar -

Drill - 24 feet - 6.66 minutes - 3.6 feet/minute

Pressures (psi):
Rotation - 900 - 1,000
Feed -1,000
Air 84

10. 3-8 - 22° - 15°

+15 feet Mm* (hard)

Collar -

Drill - 6.84 minutes - 3.22 feet/minute

Pressures (psi):
Rotation - 1,200 - 1,400
Feed - 1,000 - 1,100
Air 84

11. 3-8 - 22° - 15°

+7 feet Mm* (hard)

Collar -

Drill - 6.10 minutes - 3.6 feet/minute

Pressures (psi):
Rotation - 1,200 - 1,400
Feed - 1,000
Air - 84

* Mm = Mahogany marker.

12. 3-8 - 22^{o} - 15^{o}

-15 feet Mm* (soft)

Collar - .28

Drill - 4.28 minutes - 5.14 feet/minute

Pressures (psi):
Rotation - 1,000 - 1,200
Feed - 800 - 1,000
Air - 84

13. 3-8 - 22^{o} - 15^{o}

-15 feet Mm* (soft)

Collar - .21

Drill - 3.19 minutes - 6.89 feet/minute

Pressures (psi):
Rotation - 1,100
Feed - 650 - 800
Air 88

14. 3-4 - 24^{o} - 16^{o}

+15 feet Mm* (hard)

Collar - .23

Drill - 7.02 minutes - 3.13 feet/minute

Pressures (psi):
Rotation - 1,000 - 1,300
Feed - 900 - 1,000
Air 90

15. 3-4 - 24^{o} - 16^{o}

+4 feet Mm* (hard)

Collar - .26

Drill - 5.64 minutes - 3.9 feet/minute.

Pressures (psi):
Rotation - 1,200 - 1,500
Feed - 1,000
Air 88

* Mm = Mahogany marker.

16. 3-4 - 24° - 16°

-3 feet Mn* (hard)

Collar - .25

Drill - 9.59 minutes - 2.29 feet/minute

Pressures (psi):
Rotation - 1,200 - 1,500
Feed - 750 - 900
Air - 88

17. 1-8 - 32° - 26°

-15 feet Mn* (soft)

Collar - .15

Drill - 3.40 minutes - 6.47 feet/minute

Pressures (psi):
Rotation - 1,200 - 1,400
Feed - 750 - 900
Air - 88

18. 1-4 Standard Reground - 20° - 14°

+15 feet Mn* (hard)

Collar - .23

Drill - 7.32 minutes - 3.0 feet/minute

Pressures (psi):
Rotation - 1,000 - 1,200
Feed - 900 - 1,000
Air 92

19. 1-4 Standard Regound

+4 feet Mn* (hard)

Collar -

Drill - 7.09 minutes - 3.1 feet/minute

Pressures (psi):
Rotation - 1,000 - 1,200
Feed - 900 - 1,000
Air 90

* Mn = Mahogany marker.

20. 1-4 Standard Reground - 20° - 14°

-3 feet Mm* (hard)

Collar - .28

Drill - 14.62 minutes - 1.5 feet/minute (bit very dull)

Pressures (psi):
Rotation - 1,100 - 1,400
Feed - 900 - 1,000
Air 90

21. 1-8 Standard Reground - 21° - 15°

-15 feet Mm* (soft)

Collar - .25

Drill - 4.4 minutes - 4.97 feet/minute

Pressures (psi):
Rotation - 1,000
Feed - 650 - 800
Air - 90

* Mm = Mahogany marker.

BIT TEST - J.E.D.-1 JUMBO ACTUAL HORSEPOWER REQUIREMENTS

1-8 32°T - 6°R = 26° angle +15 feet Mm*= 17,100 psi - 2.5 feet/minute (chipped carbide)

Rotation Pressure:	hydraulic	- 1,250 psi	
	torque	- 631 foot-lbs	- 12.0 H.P.
Feed Pressure:	hydraulic	- 1,000 psi	
	thrust	- 9,045 lbs	- .68 H.P.

1-4 32°T - 6°R = 26° angle +4 feet Mm*= 17,100 psi - 3.28 feet/minute (broken carbide)

Rotation Pressure:	hydraulic	- 1,100 psi	
	torque	- 532 foot-lbs	- 10.1 H.P.
Feed Pressure:	hydraulic	- 1,200 psi	
	thrust	-13,567 lbs	- 1.34 H.P.

2-8 30°T - 6°R = 22° angle + 15 feet Mm*= 17,100 psi - 2.63 feet/minute

Rotation Pressure:	hydraulic	- 1,200 psi	
	torque	- 598 foot-lbs	- 11.39 H.P.
Feed Pressure:	hydraulic	- 1,200 psi	
	thrust	-13,567 lbs	- 1.34 H.P.

2-8 30°T - 8°R = 22° angel +4 feet Mm*= 17,100 psi - 3.55 feet/minute (two broken carbides)

Rotation Pressure:	hydraulic	- 1,200 psi	
	torque	- 598 foot-lbs	- 11.39 H.P.
Feed Pressure:	hydraulic	- 1,000 psi	
	thrust	- 9,045 lbs	- .97 H.P.

2-4 30°T - 6°R = 24° angle -6 feet Mm*= 11,700 psi - 6.36 feet/minute

Rotation Pressure:	hydraulic	- 1,400 psi	
	torque	- 731 foot-lbs	- 20.88 H.P.
Feed Pressure:	hydraulic	- 1,100 psi	
	thrust	-11,306 lbs	- 1.10 H.P.

2-4 30°T - 6°R = 24° angle -14 feet Mm*= 7,300 psi - 4.89 feet/minute (broken carbide)

Rotation Pressure:	hydraulic	- 1,400 psi	
	torque	- 731 foot-lbs	- 20.88 H.P.
Feed Pressure:	hydraulic	- 900 psi	
	thrust	- 6,784 lbs	- 1.00 H.P.

2-4 30°T - 6°R = 24° angle -6 feet Mm*= 11,700 psi - 4.73 feet/minute

Rotation Pressure:	hydraulic	- 1,250 psi	
	torque	- 631 foot-lbs	- 12.00 H.P.
Feed Pressure:	hydraulic	- 1,000 psi	
	thrust	- 9,045 lbs	- 2.11 H.P.

* Mm = Mahogany marker.

2-4 30°T - 6°R = 24° angle -8 feet Mm*= 12,000 psi - 4.12 feet/minute (broken carbide)

Rotation Pressure: hydraulic - 1,200 psi
torque - 598 foot-lbs - 17.08 H.P.
Feed Pressure: hydraulic - 800 psi
thrust - 4,522 lbs - .56 H.P.

3-8 22°T - 7°R = 15° angle -3 feet Mm*= 19,000 psi - 3.61 feet/minute

Rotation Pressure: hydraulic - 1,100 psi
torque - 532 foot-lbs - 10.12 H.P.
Feed Pressure: hydraulic - 1,000 psi
thrust - 9,045 lbs - .98 H.P.

3-8 22°T - 7°R - 15° angle - +15 feet Mm*= 17,100 psi - 3.22 feet/minute

Rotation Pressure: hydraulic - 1,400 psi
torque - 731 foot-lbs - 13.92 H.P.
Feed Pressure: hydraulic - 1,100 psi
thrust -11,306 lbs - 1.10 H.P.

3-8 22°T - 7°R = 15° angle +7 feet Mm*= 17,000 psi - 3.6 feet/minute

Rotation Pressure: hydraulic - 1,400 psi
torque - 731 foot-lbs - 13.9 H.P.
Feed Pressure: hydraulic - 1,000 psi
thrust - 9,045 lbs - .98 H.P.

3-8 22°T - 7°R = 15° angle -15 feet Mm*= 7,300 psi - 5.1 feet/minute

Rotation Pressure: hydraulic - 1,200 psi
torque - 598 foot-lbs - 17.08 H.P.
Feed Pressure: hydraulic - 1,000 psi
thrust - 9,045 lbs - 1.41 H.P.

3-8 22°T - 7°R = 15° angle -15 feet Mm*= 7,300 psi - 6.9 feet/minute

Rotation Pressure: hydraulic - 1,100 psi
torque - 532 foot-lbs - 15.18 H.P.
Feed Pressure: hydraulic - 800 psi
thrust - 4,523 lbs - .94 H.P.

3-4 24°T - 8°R = 16° angle +15 feet Mm*= 17,100 psi - 3.13 feet/minute

Rotation Pressure: hydraulic - 1,300 psi
torque - 665 foot-lbs - 12.65 H.P.
Feed Pressure: hydraulic - 1,000 psi
thrust - 9,045 lbs - .85 H.P.

3-4 24°T - 8°R = 16° angle +4 feet Mm*= 17,100 psi - 3.9 feet/minute

Rotation Pressure: hydraulic - 1,500 psi
torque - 797 foot-lbs - 15.18 H.P.
Feed Pressure: hydraulic - 1,000 psi
thrust - 9,045 lbs - 1.28 H.P.

* Mm = Mahogany marker.

3-4 24°T - 8°R = 16° angle -3 feet Mm*= 19,000 psi - 2.29 feet/minute

Rotation Pressure:	hydraulic - 1,500 psi	
	torque - 797 foot-lbs	- 15.18 H.P.
Feed Pressure:	hydraulic - 1,000 psi	
	thrust - 9,045 Lbs	- .63 H.P.

1-8 32°T - 6°R = 26° angle -15 feet Mm*= 7,300 psi - 6.47 feet/minute

Rotation Pressure:	hydraulic - 1,400 psi	
	torque - 731 foot-lbs	- 24.88 H.P.
Feed Pressure:	hydraulic - 900 psi	
	thrust - 6,784 lbs	- 1.33 H.P.

1-4 20°T - 6°R = 14° angle +15 feet Mm*= 17,100 psi - 3.01 feet/minute

Rotation Pressure:	hydraulic - 1,200 psi	
	torque - 598 foot-lbs	- 11.39 H.P.
Feed Pressure:	hydraulic - 1,000 psi	
	thrust - 9,045 lbs	- .83 H.P.

1-4 20°T - 6°R = 14° angle +4 feet Mm*= 17,000 psi - 3.16 feet/minute

Rotation Pressure:	hydraulic - 1,200 psi	
	torque - 598 foot-lbs	- 11.39 H.P.
Feed Pressure:	hydraulic - 1,000 psi	
	thrust - 9,045 lbs	- .86 H.P.

1-4 20°T - 6°R = 14° angle -3 feet Mm*= 17,000 psi - 1.5 feet/minute

Rotation Pressure:	hydraulic - 1,400 psi	
	torque - 731 foot-lbs	- 13.9 H.P.
Feed Pressure:	hydraulic - 1,100 psi	
	thrust -11,306 lbs	- .51 H.P.

1-8 21°T - 7°R = 15° angle -15 feet Mm*= 7,300 psi - 4.98 feet/minute

Rotation Pressure:	hydraulic - 1,000 psi	
	torque - 465 foot-lbs	- 13.28 H.P.
Feed Pressure:	hydraulic - 800 psi	
	thrust - 4,523 lbs	- .68 H.P.

* Mm = Mahogany marker.

SUMMARY:

The third phase dealt with the testing of precision sharpened drag bits on the Anvil Points mine face jumbo. These bits were used to drill horizontal holes for a commercial size round. The biggest problem in the drilling of a face round is the difference in drilling characteristics from high to low grade oil shale. The face round is half high and half low grade.

Results from this phase indicate that rotary drilling of high grade oil shale attains good penetration rates. Slower penetration rates were attained in the low grade shale. Bit life in the high grade shale was far better than in the low grade shale.

In this test, chipping of the carbides in certain bits became a problem, although it did not seem to slow down the penetration rates.

The horsepower requirements for each individual hole are listed on pages 37 through 39. These are somewhat low compared to previous tests at other oil shale mines.

CONCLUSION:

The drill and bit test indicated that straight rotary drilling with conventional drag bits attained the best penetration rates. The rotary percussion drilling, using the Mission Megadrill, performed poorly which was mainly due to the lack of rotary percussion type bits or some other bit type that would hold up under percussion drilling. Future testing with rotary percussion type drilling equipment should be looked into.

Feed pressure control indicated that the bit's clearance angle is the governing factor in the amount of feed pressure needed to attain the best penetration rates. Different bits with different clearance angles performed best at varying pressures. Some bits performed well at all feed pressures.

WWM/vc
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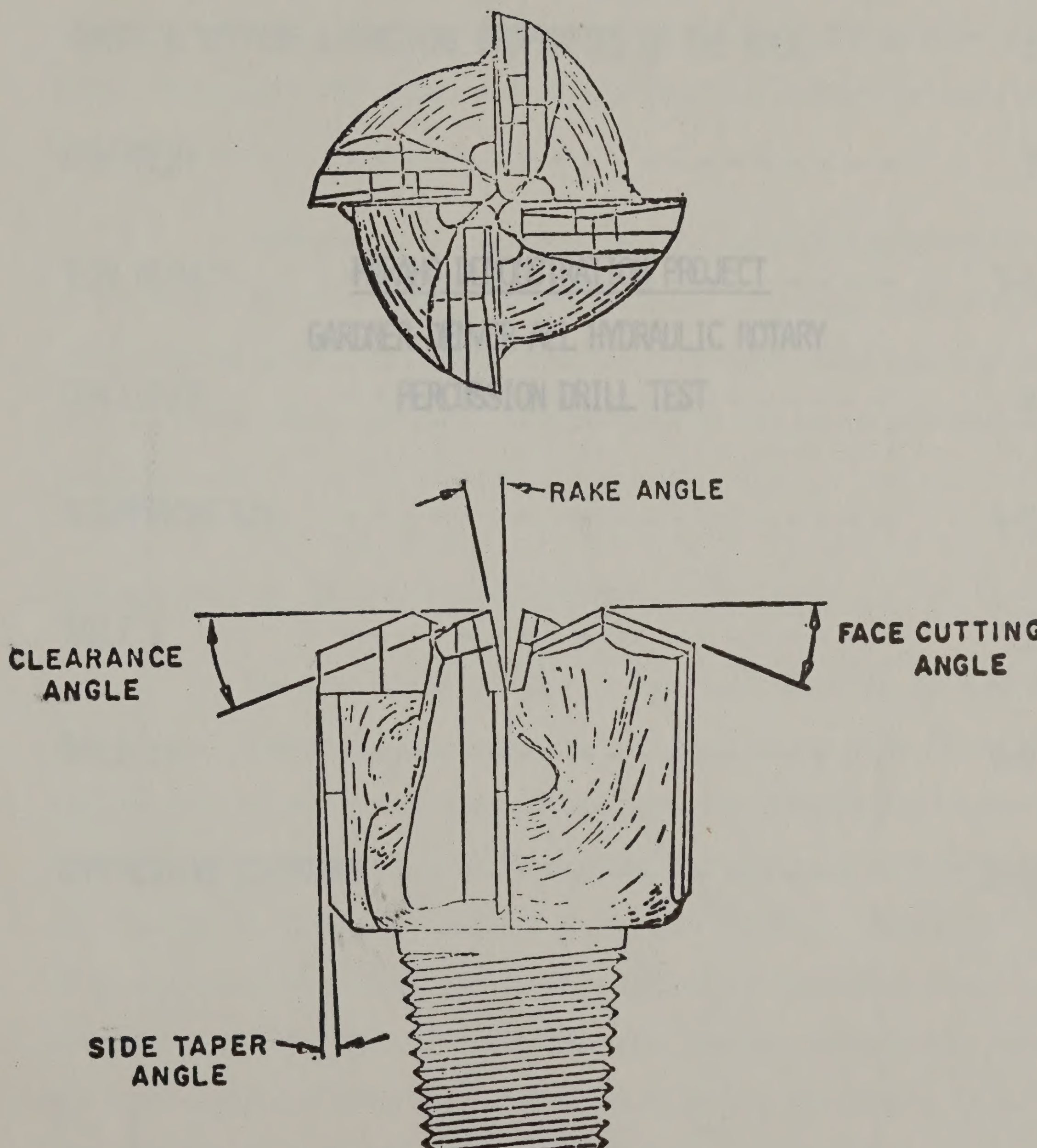
FIGURE 1

4 INCH DRAG BIT



PARAHO DEMONSTRATION PROJECT

GARDNER-DENVER ALL HYDRAULIC ROTARY PERCUSSION DRILL TEST

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GARDNER-DENVER ALL HYDRAULIC ROTARY PERCUSSION DRILL TEST

INTRODUCTION:

For two weeks in January of 1976, Gardner-Denver Company furnished a prototype all hydraulic rotary percussion drill jumbo for testing at the Paraho Demonstration Project's Anvil Points mine near Rifle, Colorado. The total cost of the test was assumed by the Gardner-Denver Company.

This test was conducted in an area of the mine where a complete section of the face was accessible. Both high grade (soft) and low grade (hard) zones were drilled. Gardner-Denver came prepared with an ample supply of bits, both percussion and rotary percussion in sizes up to 4".

PHYSICAL SETTING AND PHYSICAL PROPERTIES OF THE ROCK:

The rich shale drilled in this test was 7 to 15 feet below the Mahogany marker. Oil content of this rock ranges from 21 to 86 gallons per ton with rock compressive strengths ranging from 8,000 to 16,500 pounds per square inch. The rich shale is weak rock having a low modulus of elasticity and a high Poisson's ratio. Percussion energy from percussion or rotary percussion drilling is apparently easily dissipated in this type of rock. For this reason, penetration rates in the rich shale are lower for percussion or rotary percussion drilling than for straight rotary drilling.

The lean shale zones predominately lie above and immediately below the Mahogany marker. The lean shale is strong having a high modulus of elasticity and a low Poisson's ratio. The lean zones drilled in this test are near the Mahogany marker. Oil content of this rock ranges from 9 to 16 gallons per ton with rock compressive strengths ranging from 18,000 to 24,000 pounds per square inch.

Rotary percussion drilling in lean shale zones attains higher penetration rates than straight rotary or percussion drilling.

EQUIPMENT:

Gardner-Denver Company furnished a Universal -3 diesel powered jumbo carrier equipped with electric powered hydraulic systems to test two HPR-1 all hydraulic rotary percussion drills. The electric motors used to power the hydraulic systems are each rated at 75 horsepower. Each drill develops 400,000 to 500,000 foot pounds of energy per minute, depending on the percussion stroke setting. The percussion function of the drill machine can be adjusted to one of four settings. These settings with approximate blows per minute, foot pounds per blow and foot pounds per minute are found in Table I.

TABLE I

GAUGE SETTING HYDRAULIC PRESSURE IN LBS/SQ INCH	BLOWS PER MINUTE	FOOT POUNDS PER BLOW	FOOT POUNDS PER MINUTE
1,500	2,500	200	500,000
1,000	3,000	166	498,000
750	3,500	133	465,500
0	4,000	100	400,000

Gardner-Denver indicated that the jumbo and drills, as a unit, were not specifically designed for drilling in oil shale. Although the unit was not designed for drilling in oil shale, it is felt that hydraulic rotary percussion drilling will have some type of application in the development of oil shale.

Resharpening of bits was possible as Gardner-Denver furnished a bit grinding machine. This made testing of various bits with different angles possible.

TEST RESULTS:

As a whole, penetration rates attained in this test were equivalent to those of previously tested rotary percussion drills. Table II (pages 6,7,8 & 9) lists various sized bits tested in different shale horizons ($\pm$ Mahogany marker) with the four percussion stroke settings. The bits are both percussion and rotary percussion type ranging in size from 2" to 4". Graphs were plotted with respect to the four percussion stroke settings as well as penetration rates versus oil shale grades. Along with these grades are the approximate corresponding compressive strengths. These are included on pages 10, 11, 12 and 13. All the penetration rates on these graphs are for 4" bits. Most of the larger bits tested (3" to 4") were of the percussion type. After testing of the percussion bits, some of them were reground to simulate rotary percussion type bits. Overall, rotary percussion type bits attained the best penetration rates but a few percussion type bits did drill as fast.

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TEST RESULTS:

The best penetration rates in all areas drilled (hard and soft) were attained while drilling on percussion stroke settings of 1,500 and 1,000 psi. These two settings have the fewest blows per minute but the most foot pounds per blow. This would indicate that there is a direct relationship between the amount of energy introduced and the penetration rates attained.

The bit type made a large difference in the penetration rate. Percussion bits reground to simulate rotary percussion type bits attained the best penetration rates. More testing with different bit angles needs to be done in order to substantiate the optimum of angles for the drilling of oil shale.

CONCLUSION:

The Gardner-Denver HPR-1 all hydraulic rotary percussion drill performed well in the low grade shale zones but penetration rates in the high grade shale zones were poor. Overall drill potential seems to be good but combined with inadequate bit design, overall penetration rates do not meet those of conventional rotary drilling.

RECOMMENDATIONS:

Gardner-Denver has a larger prototype all hydraulic rotary percussion drill in the building stages. It is suggested that when this unit is available that it be tested in the drilling of oil shale.

Bit design, with respect to rotary percussion type for drilling experiments in oil shale, is far behind drill development. It is recommended that a major bit manufacturer be persuaded to enter these experiments with new bit designs.

TABLE II

BIT* SIZE	± MAHOGANY MARKER	TIME TO DRILL 12' (Minutes)	FEET PER MINUTE	CONVERSION TO 4" BIT TIME (Feet/Minute)	PERCUSSION HAMMER STROKE SETTING
2"	-7	1.85	6.49	2.30	750
2"	-3	2.04	5.88	2.08	750
2"	+1	2.35	5.11	1.81	750
2"	-1	2.10	5.71	2.02	1,000
2"	-2	1.85	6.49	2.30	1,000
2"	-7	2.20	5.45	1.93	1,000
2"	-11	2.38	5.04	1.78	1,000
2"	-15	4.57	2.63	.93	1,000
2"	-15	5.21	2.30	.81	750
2"	-11	2.55	4.71	1.68	750
3"	-5	3.84	3.13	2.03	750
3"	-5	3.76	3.19	2.07	1,000
3"	-5	3.22	3.73	2.42	1,500
3"	-3.5	2.50	4.80	3.12	1,500
3"	-3.5	2.26	5.31	3.45	1,000
3"	-3.5	2.66	4.51	2.93	750
3"	-3.5	3.13	3.83	2.49	-0-
3"	0	3.23	3.71	2.41	1,500
3"	0	2.90	3.14	2.04	1,000
3"	0	3.30	3.64	2.37	750
3"	0	4.34	2.76	1.79	-0-
3"	+1.5	3.70	3.24	2.11	1,500

* Bits are both percussion and rotary percussion type.

TABLE II
(Continued)

BIT* SIZE	± MAHOGANY MARKER	TIME TO DRILL 12' (Minutes)	FEET PER MINUTE	CONVERSION TO 4" BIT TIME (Feet/Minute)	PERCUSSION HAMMER STROKE SETTING
4"	+1	3.92	3.06	3.06	1,500
4"	+1	3.95	3.04	3.04	1,500
4"	-6	3.72	3.23	3.23	1,500
4"	+1	4.92	2.44	2.44	1,500
4"	-14	6.45	1.86	1.86	1,500
4"	-3	3.50	3.43	3.43	1,500
2½	-14	2.65	4.53	2.24	1,500
2½	-14	3.36	3.57	1.77	1,000
2½	-14	3.46	3.47	1.72	750
2½	-14	3.43	3.50	1.73	-0-
2½	-11	2.33	5.15	2.55	1,500
2½	-11	2.64	4.54	2.25	1,000
2½	-11	2.60	4.62	2.29	750
2½	-11	3.78	3.17	1.57	-0-
2½	-8	2.80	4.28	2.12	1,500
2½	-8	3.19	3.76	1.86	750
2½	-8	3.60	3.33	1.65	-0-
2½	-8	2.07	5.80	2.87	1,000
3"	-1	3.37	3.56	2.31	1,000
3"	-1	3.52	3.41	2.22	750
3"	-1	4.05	2.96	1.92	-0-
3"	-3	3.10	3.87	2.51	1,500

* Bits are both percussion and rotary percussion type.

TABLE II
(Continued)

BIT* SIZE	± MAHOGANY MARKER	TIME TO DRILL 12' (Minutes)	FEET PER MINUTE	CONVERSION TO 4" BIT TIME (Feet/Minute)	PERCUSSION HAMMER STROKE SETTING
3"	-3	2.66	4.51	2.93	1,000
3"	-3	2.63	4.56	2.96	750
3"	-3	3.15	3.81	2.48	-0-
3"	-7	2.33	5.15	3.35	1,500
3"	-7.5	2.42	4.96	3.22	1,000
3"	-7.5	2.62	4.58	2.98	750
3"	-7.5	3.50	3.43	2.23	-0-
3"	-11	2.78	4.32	2.80	1,500
3"	-11	2.87	4.18	2.72	1,000
3"	-11	3.23	3.72	2.42	750
3"	-11	4.24	2.83	1.84	-0-
3"	-15	3.78	3.17	2.06	1,500
3"	-15	4.05	2.96	1.92	1,000
3"	-15	4.80	2.50	1.62	750
3"	-15	6.63	1.81	1.18	-0-
4"	-1	3.50	3.43	3.43	1,500
4"	-1	4.25	2.82	2.82	1,000
4"	-1	4.28	2.80	2.80	750
4"	-1	4.90	2.45	2.45	-0-
4"	-3	3.34	3.59	3.59	1,500
4"	-3	3.00	4.00	4.00	1,000

* Bits are both percussion and rotary percussion type.

TABLE II
(Continued)

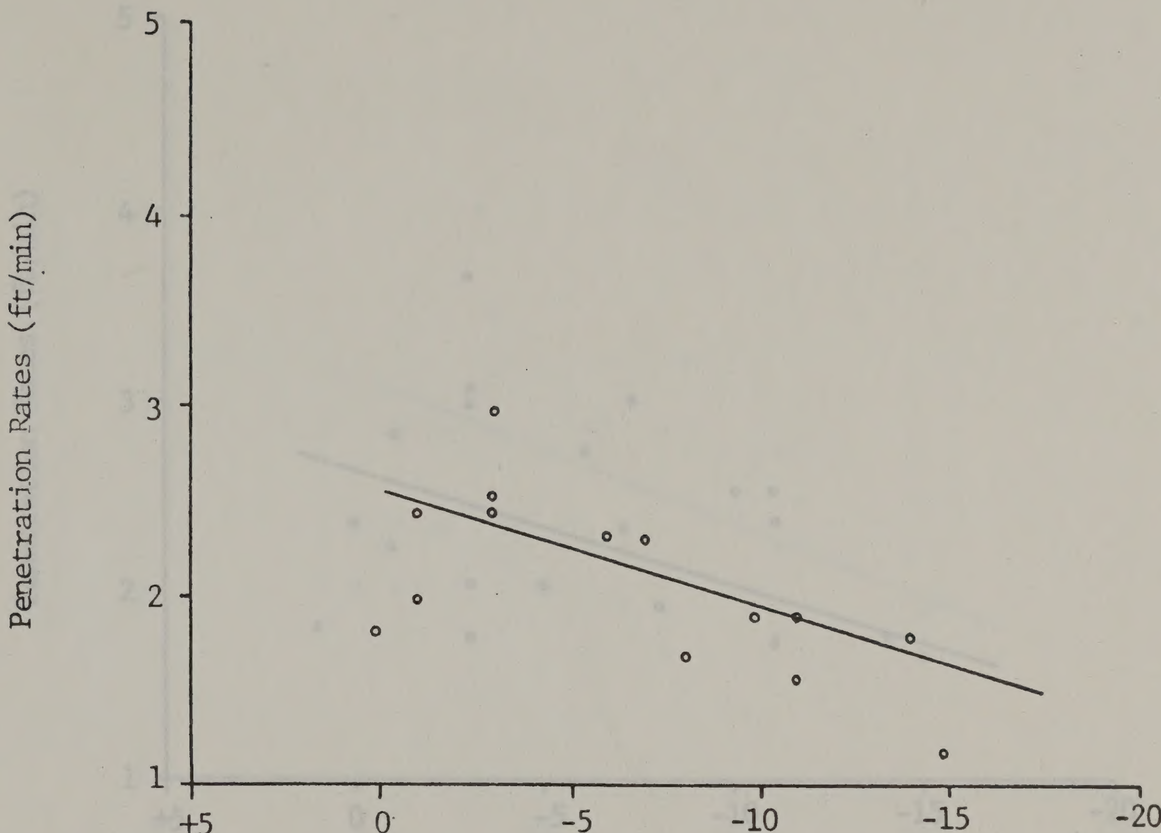
BIT* SIZE	± MAHOGANY MARKER	TIME TO DRILL 12' (Minutes)	FEET PER MINUTE	CONVERSION TO 4" BIT TIME (Feet/Minute)	PERCUSSION HAMMER STROKE SETTING
4"	-3	3.32	3.61	3.61	750
4"	-3	4.12	2.91	2.91	-0-
4"	-7	3.90	3.08	3.08	1,500
4"	-6	4.20	2.85	2.85	1,000
4"	-6	4.47	2.68	2.68	750
4"	-6	5.23	2.29	2.29	-0-
4"	-10	4.42	2.71	2.71	1,500
4"	-10	5.05	2.38	2.38	1,000
4"	-10	4.80	2.50	2.50	750
4"	-10	6.50	1.85	1.85	-0-
4"	-15	8.00	1.50	1.50	1,500

Conversion factor to 4" bit penetration rates:

3" to 4"	x .650
2½" to 4"	x .495
2¼" to 4"	x .442
2" to 4"	x .354

* Bits are both percussion and rotary percussion type.

Results with 0 psi percussion hammer stroke gauge setting, 4,000 blows per minute at 100 foot pounds per blow. All penetration rates are for 4" bits.

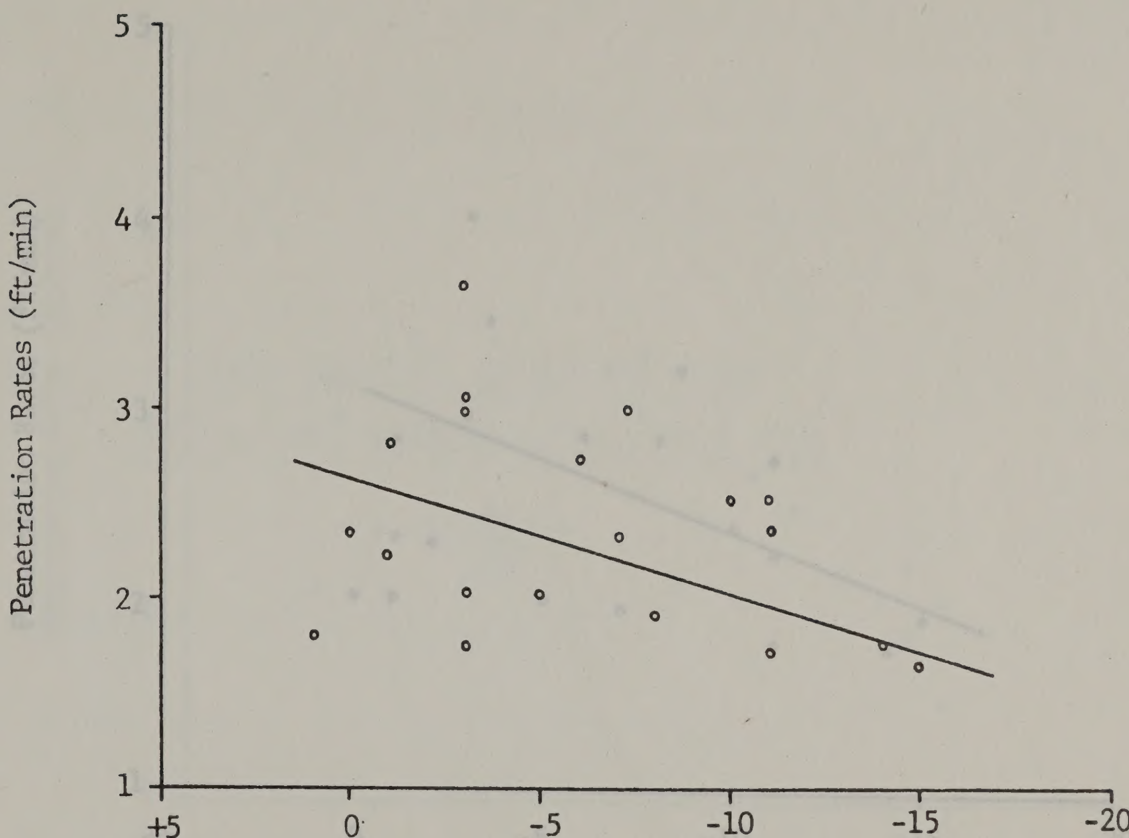


Face location with respect to Mahogany marker with approximate grade and compressive strength in the following Table:

Face Location (± Mm)	-1	-3	-7	-11	-15
Grade (gal/ton)	9.9	11.1	46.3	21.4	86.6
Approximate Compressive Strength (lbs/sq in)	24,000	23,000	9,500	16,500	8,000

GARDNER-DENVER ALL HYDRAULIC ROTARY PERCUSSION DRILL TEST

Results with 750 psi percussion hammer stroke gauge setting, 3,500 blows per minute at 133 foot pounds per blow. All penetration rates are for 4" bits.

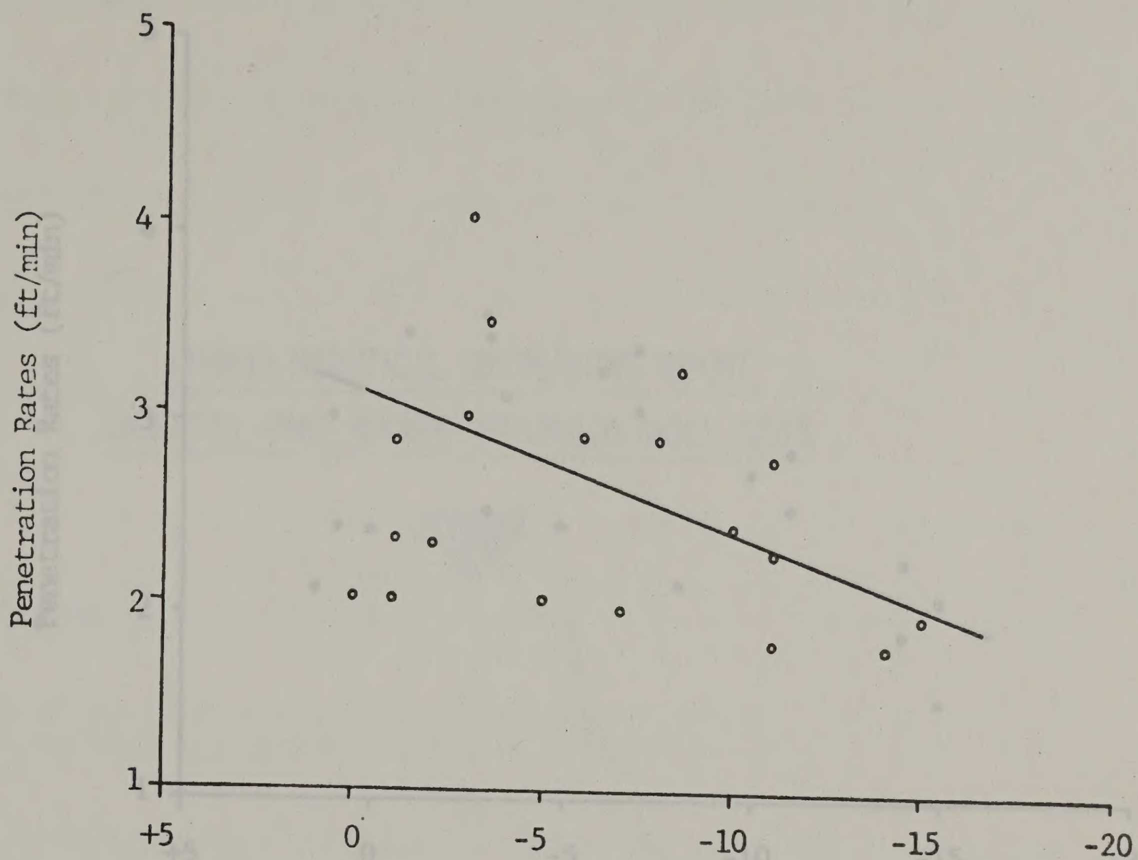


Face location with respect to Mahogany marker with approximate grade and compressive strength in the following Table:

Face Location (± Mm)	-1	-3	-7	-11	-15
Grade (gal/ton)	9.9	11.1	46.3	21.4	86.6
Approximate Compressive Strength (lbs/sq in)	24,000	23,000	9,500	16,500	8,000

GARDNER-DENVER ALL HYDRAULIC ROTARY PERCUSSION DRILL TEST

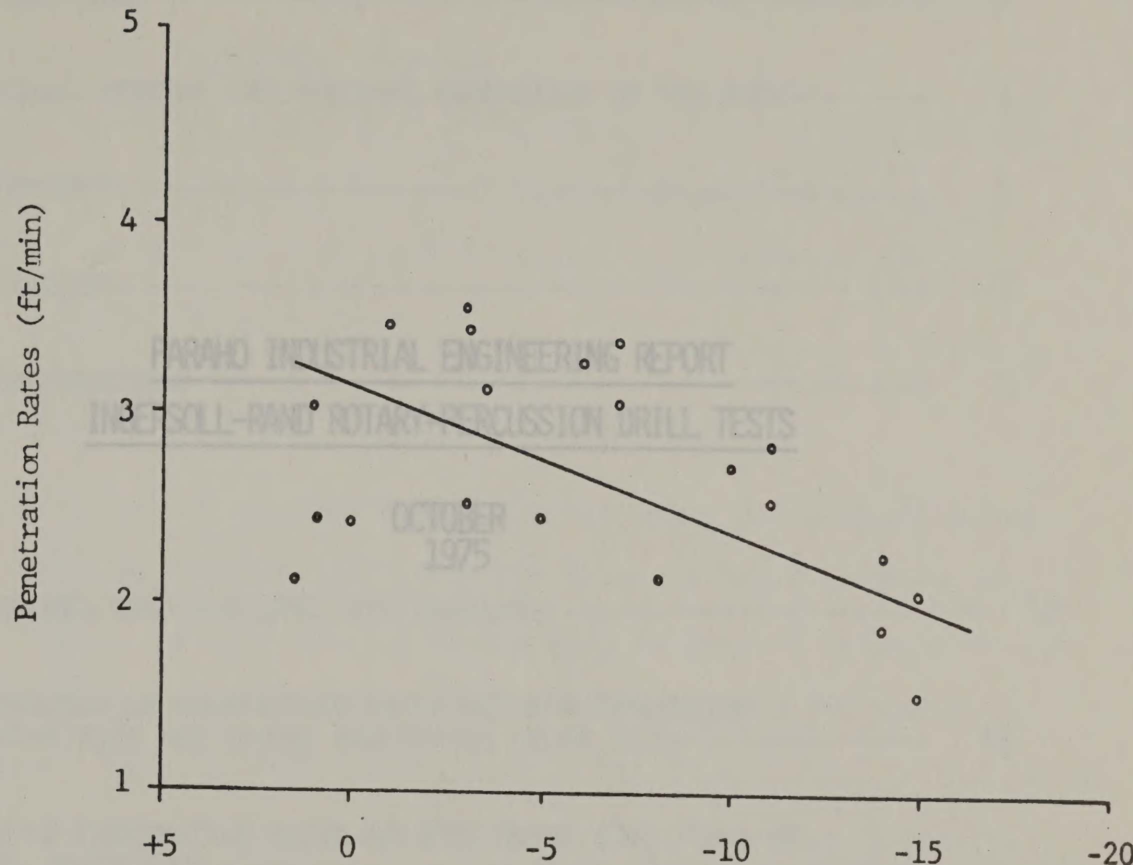
Results with 1,000 psi percussion hammer stroke gauge setting, 3,000 blows per minute at 166 foot pounds per blow. All penetration rates are for 4" bits.



Face location with respect to Mahogany marker with approximate grade and compressive strength in the following Table:

Face Location (± Mn)	-1	-3	-7	-11	-15
Grade (gal/ton)	9.9	11.1	46.3	21.4	86.6
Approximate Compressive Strength (lbs/sq in)	24,000	23,000	9,500	16,500	8,000

Results with 1,500 psi percussion hammer stroke gauge setting, 2,500 blows per minute at 200 foot pounds per blow. All penetration rates are for 4" bits.



Face location with respect to Mahogany marker with approximate grade and compresssive strength in the following Table:

Face Location (± Mm)	-1	-3	-7	-11	-15
Grade (gal/ton)	9.9	11.1	46.3	21.4	86.6
Approximate Compressive Strength (lbs/sq in)	24,000	23,000	9,500	16,500	8,000

PARAHO INDUSTRIAL ENGINEERING REPORT
INGERSOLL-RAND ROTARY-PERCUSSION DRILL TESTS

OCTOBER
1975

BY

WES MOULTON
GEOLOGICAL ENGINEER

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INGERSOLL-RAND TEST

1. INTRODUCTION

This test was conducted at the Paraho Demonstration Project's Anvil Points mine near Rifle, Colorado.

The section of oil shale being mined consists of both rich and lean zones with an average oil content of about 30 gallons per ton. Drillability of rich and lean shale zones differs greatly as each has definite physical characteristics.

2. PHYSICAL SETTING AND PHYSICAL PROPERTIES OF THE ROCK

The bulk of the rich shale zones lie below the Mahogany Marker but the rich zone drilled in this test was seven to nine feet above the Mahogany Marker. The oil content in this rock is 33 to 38 gallons per ton with rock compressive strengths ranging from 10,000 to 12,000 pounds per square inch. The rich shale is weak rock having a low modulus of elasticity and a high Poisson's Ratio. Percussion energy of percussion or rotary-percussion drilling is apparently easily dissipated in this type of rock. This is why in the rich shale the penetration rate is lower for percussion or rotary-percussion drilling than for rotary drilling.

The lean shale zones predominately lie above and immediately below the Mahogany Marker. The lean shale is strong and has a high modulus of elasticity and a low Poisson's Ratio. The lean zones used in this test are near the Mahogany Marker. The oil content in these zones ranges

from 8 to 24 gallons per ton with compressive strengths ranging from 15,000 to 20,000 pounds per square inch. Rotary-percussion drilling in lean shale zones seems to attain higher penetration rates than straight rotary or percussion drilling.

3. EQUIPMENT

Ingersoll-Rand Company furnished a 96 M.J.M. diesel powered jumbo carrier equipped with an electric powered hydraulic system to test a Hard III all hydraulic rotary-percussion drill. The electric motor used to power the hydraulic system is rated at 150 H.P. The drill develops 600,000 foot pounds of energy per minute. Input horsepower ratings used in the hammer, rotation and thrust are as follows:

1.	HAMMER:	40.00 H.P.
2.	ROTATION:	8.75 H.P.
3.	THRUST:	1.50 H.P.
	TOTAL	50.25 H.P.

This drill was tested on four different days with twenty-eight holes drilled. The holes are recorded under the date drilled in Table I. Table II compares penetration rates of percussion cross bits to penetration rates of ground percussion cross bits. One 1-7/8" bit was not ground as it was a rotary-percussion bit. The 3" bits were ground down to simulate a rotary-percussion bit. As can be seen in the table, an increase in penetration rates were attained with the ground percussion bit. Most penetration rates for the ground percussion bits doubled the penetration rates for the straight percussion bits. Only 3" and 1-7/8" bits are included in Table II.

Tables III and III-A are plots of penetration rates against grade (gallons per ton) of oil shale rock. All numbers on the plots are recorded penetration rates for a 3" bit or calculated rates from other size bits.

4. CONCLUSION

The Ingersoll-Rand Hard III rotary-percussion drill performed well in the lean shale zones but penetration rates in the rich shale zones were poor. Overall drill potential seems to be good but combined with inadequate bit design and poor bit supply, overall penetration rates do not meet those of conventional rotary drilling.

5. RECOMMENDATIONS

It is recommended that Ingersoll-Rand meet with The Cleveland-Cliffs Iron Company to discuss future potential for their rotary percussion unit.

Bit design and supply with respect to rotary-percussion type drills for drilling experiments in oil shale rock are far behind drill development. It is recommended that a major bit manufacturer be persuaded to enter these experiments with new bit designs and adequate supplies of bits.

Recommendations regarding the Ingersoll-Rand 96 M.J.M. jumbo's hydraulic system are to utilize the rigs two hydraulic pumps by separating the feed hydraulic's system from the drill hydraulic's system. This would increase the feed and drill pressures which, in turn, would hopefully increase penetration rates.

TABLE I

Ingersoll-Rand Drilling Test Results

8-21-75

#1 ± Mahogany Marker +2.5 feet

Bit - 3" Percussion Cross Bit

Collar - Not available

Drill - 7 feet in 3.84 minutes = 1.82 feet/minute

Retract - Not available

#2 ± Mahogany Marker +1.0 foot

Bit - 3" Percussion Cross Bit (same bit as above)

Collar - Not available

Drill - 10 feet in 2.48 minutes = 4.03 feet/minute

Blew hydraulic pump seals

9-2-75

ALL HOLES DRILLED WITH A 4" PERCUSSION CROSS BIT

#1 ± Mahogany Marker +1.0 foot

Collar- .08 minutes

Drill - 10 feet in 5.09 minutes = 1.96 feet/minute

Retract - .32 minutes

Pressures - PSI:

Feed - 1250

Drill - 3150

Rotary - Not available

#2 ± Mahogany Marker -1'2"

Collar - .10 minutes

Drill - 10 feet in 7.04 minutes = 1.42 feet/minute

Retract - Not available

Pressures - PSI:

Feed - 1250

Drill - 3150

Rotary - Not available

#3 ± Mahogany Marker - 2'4"

Collar - .09 minutes

Drill - 10 feet in 6.65 minutes = 1.50 feet/minute

Retract - .35 minutes

Pressures - PSI:

Feed - 1250

Drill - 3150

Rotary - Not available

#4 ± Mahogany Marker + 5'7"

Collar - .07 minutes

Drill - 10 feet in 9.38 minutes = 1.07 feet/minute

Retract - .36 minutes

Pressures - PSI:

Feed - 1600

Drill - 3150

Rotary - Not available

#5 ± Mahogany Marker + 10'2"

Collar - .22 minutes

Drill - 10 feet in 8.19 minutes = 1.22 feet/minute

Retract - Not available

Pressures - PSI:

Feed - 1500

Drill - 2900

Rotary - Not available

9-3-75

#1 ± Mahogany Marker -1'2"

Collar - .10 minutes

Drill - 10 feet in 4.69 minutes = 2.13 feet/minute

Retract - .31 minutes

Pressures - PSI:

Feed - 1700

Drill - 3050

Rotary - Not available

Bit - 2 1/2" Percussion Cross Bit

#2 ± Mahogany Marker - 3'2"

Collar - .09 minutes

Drill - 10 feet in 5.90 minutes = 1.69 feet/minute

Retract - Not available

Pressures - PSI:

Feed - 1400

Drill - 3050

Rotary - Not available

Bit - 2 1/2" Percussion Cross Bit

#3 ± Mahogany Marker - 1.0 foot

Collar - .12 minutes

Drill - 10 feet in 3.07 minutes = 3.25 feet/minute

Retract - Not available

Pressures - PSI:

Feed - 1450

Drill - 3050

Rotary - Not available

Bit - 3" Button Bit

#4 ± Mahogany Marker - 4'3"

Collar - .10 minutes

Drill - 10 feet in 4.35 minutes = 2.29 feet/minute

Retract - Not available

Pressures - PSI:

Feed - 1450

Drill - 2950

Rotary - Not available

Bit - 3" Button Bit

#5 ± Mahogany Marker - 2'3"

Collar - 10 minutes

Drill - 10 feet in 4.36 minutes = 2.29 feet/minute

Retract - 36 minutes

Pressures - PSI:

Feed - 1450

Drill - 3150

Rotary - Not available

Bit - 3" Button Bit

#6 ± Mahogany Marker - 8"

Collar - .07 minutes

Drill - 10 feet in 4.75 minutes = 2.10 feet/minute

Retract - .38 minutes

Pressures - PSI:

Feed - 1400

Drill - 3000

Rotary - Not available

Bit - 3" Percussion Cross Bit

#7 ± Mahogany Marker +4'

Collar - .09 minutes

Drill - 10 feet in 5.77 minutes = 1.73 feet/minute

Retract - Not available

Pressures - PSI:

Feed - 1450

Drill - 3000

Rotary - Not available

Bit - 3" Percussion Cross Bit

9-16-75

#1 ± Mahogany Marker -9" Oil Content - 10.9 Gal/Ton

Collar - Not available

Drill - 10 feet in 2.09 minutes = 4.78 feet/minute

Retract - Not available

Pressures - PSI:

Feed - 1450

Drill - 1450

Rotary - 3000

Bit - 3" Ground Percussion Bit

#2 ± Mahogany Marker +10' Oil Content - 14.6 Gal/Ton

Collar - .11 minutes

Drill - 10 feet in 2.48 minutes = 4.03 feet/minute

Retract - .33 minutes

Pressures - PSI:

Feed - 1350

Drill - 1450

Rotary - 2950

Bit - 3" Ground Percussion Bit

#3 ± Mahogany Marker +2' Oil Content - 18.2 Gal/Ton

Collar - .12 minutes

Drill - 10 feet in 2.52 minutes = 3.96 feet/minute

Retract - .36 minutes

Pressures - PSI:

Feed - 1350

Drill - 1400

Rotary - 2800

Bit - 3" Ground Percussion Cross Bit

#4 ± Mahogany Marker -9" Oil Content - 8.0 Gal/Ton

Collar - Not available

Drill - 10 feet in 3.42 minutes = 2.92 feet/minute

Retract - .35 minutes

Pressures - PSI:

Feed - 1250

Drill - 1500

Rotary - 2750

Bit - 4" Ground Percussion Cross Bit

#5 ± Mahogany Marker +7'4" Oil Content - 38.4 Gal/Ton

Collar - Not available

Drill - 10 feet in 9.03 minutes = 1.10 feet/minute

Retract - .39 minutes

Pressures - PSI:

Feed - 1250

Drill - 1500

Rotary - 2650

Bit - 4" Ground Percussion Cross Bit

#6 ± Mahogany Marker +7'

Collar - .08 minutes

Drill - 10 feet in 4.21 minutes = 2.37 feet/minute

Retract - .31 minutes

Pressures - PSI:

Feed - 1350

Drill - 1300

Rotary - 2700

Bit - 3" Ground Percussion Cross Bit

#7 ± Mahogany Marker +7'2" Oil Content - 33.1 Gal/Ton

Collar - .11 minutes

Drill - 10 feet in 3.41 minutes = 2.93 feet/minute

Retract - .31 minutes

Pressures - PSI:

Feed - 1600

Drill - 1550

Rotary - 3150

Bit - 3" Ground Percussion Cross Bit

#8 ± Mahogany Marker +10'   Oil Content - 21.4 Gal/Ton

Collar - .10 minutes

Drill - 10 feet in 2.82 minutes = 3.54 feet/minute

Retract - .37 minutes

Pressures - PSI:

Feed - 1750

Drill - 1800

Rotary - 3200

Bit - 3" Ground Percussion Cross Bit

9 and 10

4" Button Bit - bit would collar the hole but no penetration was attained. Bit was tried in both lean and rich shale zones.

#11 ± Mahogany Marker +8'

Collar - .07 minutes

Drill - 10 feet in 4.45 minutes = 2.24 feet/minute

Retract - Not available

Pressures - PSI:

Feed - 1250

Drill - 1600

Rotary - 3150

Bit - 1 7/8" -X-Bit - Bit plugged.

#12 ± Mahogany Marker +7'6"   Oil Content - 24.4 Gal/Ton

Collar - .08 minutes

Drill - 10 feet in 4.23 minutes = 2.36 feet/minute

Retract - Not available

Pressures - PSI:

Feed - 1250

Drill - 1500

Rotary - 2950

Bit - 1 7/8" -X-Bit - Bit plugged.

#13 ± Mahogany Marker +7'5" Oil Content - 38.0 Gal/Ton

Collar - .10 minutes

Drill - 10 feet in 2.35 minutes = 4.25 feet/minute

Retract - Not available

Pressures - PSI:

Feed - 1250

Drill - 1500

Rotary - 3150

Bit - 1 7/8" Rotary Percussion Bit

#14 ± Mahogany Marker -8" Oil Content - 22 Gal/Ton

Collar - .11 minutes

Drill - 10 feet in 1.60 minutes = 6.25 feet/minute

Retract - Not available

Pressures - PSI:

Feed - 1250

Drill - 1500

Rotary - 3150

Bit - 1 7/8" Rotary Percussion Bit

TABLE II

Comparison of Penetration Rates

Between Percussion Cross Bits and Ground Percussion Cross Bits

Bit	± Mahogany Marker	Penetration Feet/Minute	Gallons/Ton
3" Percussion Cross Bit	+4' 0"	1.73	Not available
3" Percussion Cross Bit	+2' 5"	1.82	Not available
3" Ground Percussion Cross Bit	+2' 0"	3.96	18.2
3" Percussion Cross Bit	+1' 0"	4.03	Not available
3" Ground Percussion Cross Bit	-9"	4.78	10.9
3" Ground Percussion Cross Bit	+7'	2.37	Not available
3" Ground Percussion Cross Bit	+7' 2"	2.93	33.1
3" Ground Percussion Cross Bit	+10'2"	3.54	21.4
3" Percussion Cross Bit	-8"	2.10	Not available
1-7/8" Percussion Cross Bit	+7' 6"	2.36	24.4
1-7/8" Percussion Cross Bit	+8' 0"	2.24	Not available
1-7/8" Rotary Percussion Bit	+7' 5"	4.25	38.0
1-7/8" Rotary Percussion Bit	-8"	6.25	22.3

TABLE III

INGERSOLL-RAND COMPANY ROTARY PERCUSSION DRILLING

Plot of Penetration Rates Against Grade (Gal./Ton) of Oil Shale Rock

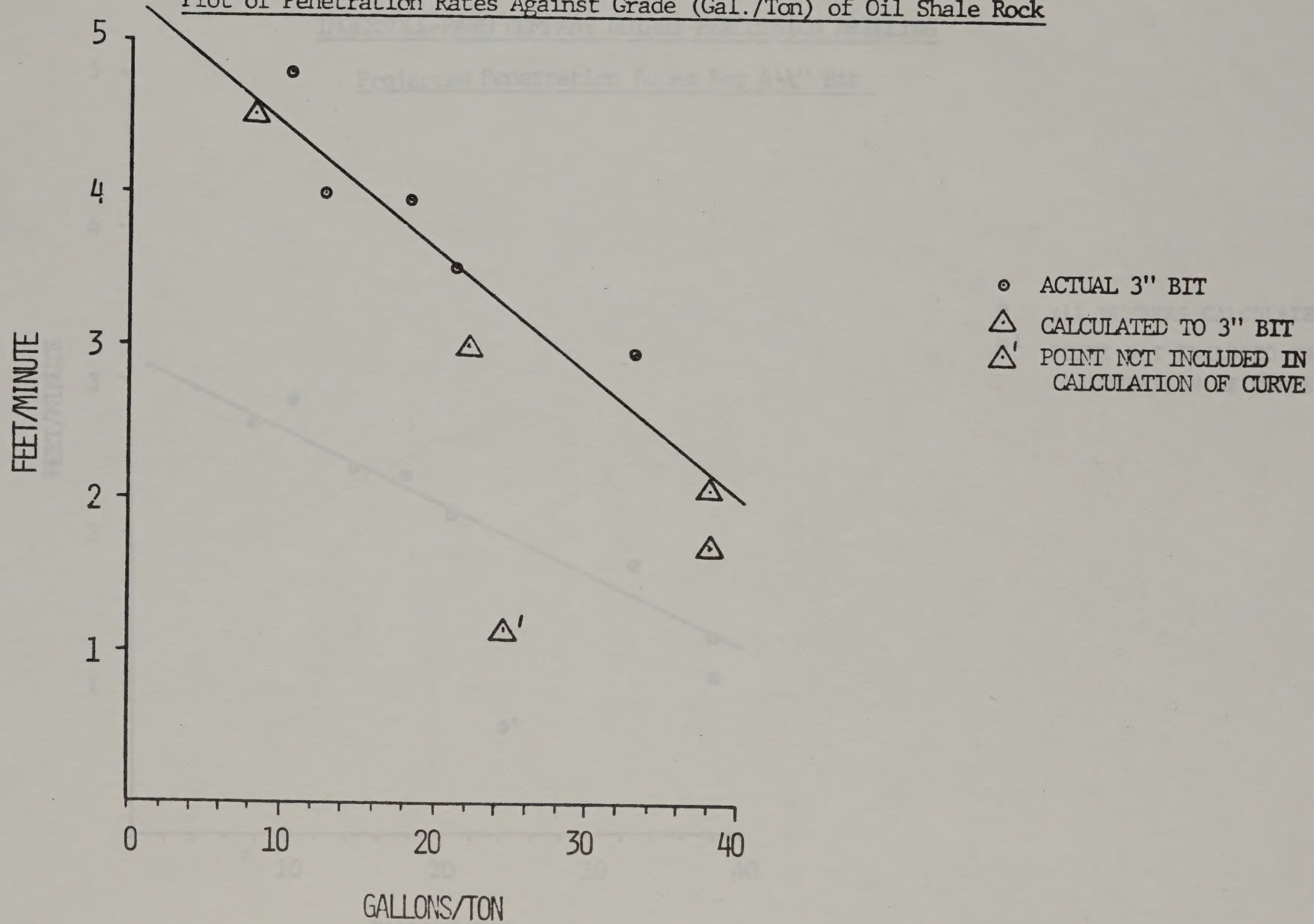
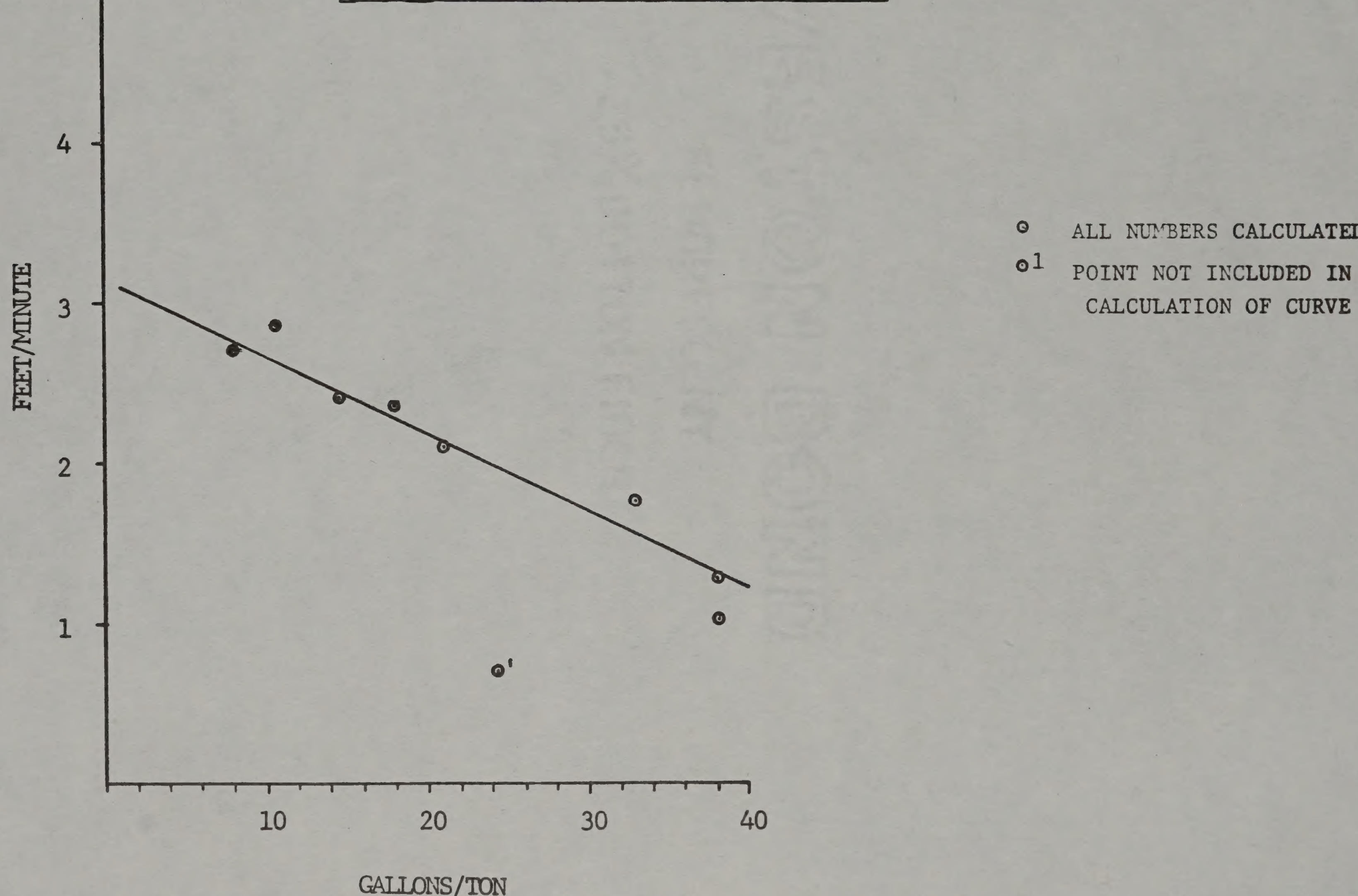


TABLE III-A

INGERSOLL-RAND COMPANY ROTARY PERCUSSION DRILLING

Projected Penetration Rates For 4-¼" Bit



PARAHO DEMONSTRATION PROJECT
JOY DRILL AND BIT TEST
DECEMBER, 1975

BY

W. W. MOULTON
GEOLOGICAL ENGINEER

JOY DRILL AND BIT TEST

INTRODUCTION:

On December 8, 1975, a Joy Mustang track drill, equipped with a Joy V.C.R. valveless, rotary percussion drill, was tested at the Paraho Demonstration Project's Anvil Points Mine near Rifle, Colorado. The Joy Mustang track drill, including all the equipment and freight charges, was furnished at no expense by Farris Equipment Company of Denver, Colorado.

Vertical holes were drilled in the floor with the hole collar located approximately 20 feet below the Mahogany Marker. These holes were drilled in medium and high grade shale.

EQUIPMENT:

The V.C.R.-280 is a valveless continuous rotation drill which consumes 1,200 cubic feet of air per minute at an air pressure of 100 pounds per square inch. The hammer operates (percussion) at 2,000 blows per minute with 386 foot pounds per blow. Rotation speed is variable with a maximum rotation of 300 revolutions per minute.

Air to operate the drill is supplied by a Joy RPS-1300 diesel-powered air compressor. This compressor is towed in back of the drill.

TEST RESULTS:

Two types of bits were tested. A 4" button bit was tested with poor results. Drilling rates averaged 2.2 feet per minute. The second bit tested was a percussion cross bit resharpened to simulate a rotary percussion bit. Twenty holes were drilled with this bit attaining an average penetration rate of 4.6675 feet per minute. (See Figure #1).

The average penetration rate combined with a potentially long bit life (one bit drilled 20 holes (360 feet) at 4.6675 feet/minute) makes this Joy drill and bit combination competitive with other drills investigated for use in future oil shale mining operations. One drawback noted during the drilling test was the amount of noise produced during the drilling cycle.

Table I is a detailed summary of the time taken to drill each hole. The holes are listed in the order they were drilled.

The operator performing the test was a demonstration operator employed by Joy.

Future study on the application of this type of drilling (rotary-percussion) to oil shale operations should be undertaken.

COST ESTIMATES:

An estimate of operating labor and supplies and maintenance labor and supplies is attached.

WWM/vc

THE CLEVELAND - CLIFFS IRON CO.
WESTERN DIVISION

PROJECT: JOY DRILLING TEST

LOWER LEVEL MINING - 3,450 TONS/DAY 23,000 TONS/WEEK

OPERATING COST - DRILLING (WET ROTARY)

A. OPERATING LABOR

Job Description	Men Per Shift	Shift Schedule	Total Shifts	Shift Rate	Cost Per Week
Drill Operator ($5.33)	1	5.3	5.3	$42.64	$ 226
Bit Sharpener ($5.29)	1	1.2	1.2	42.32	51
		Sub Total			$ 277
		Contributions @ 35 %			97
		Contributions for Absenteeism @ 1.4 %			4
		Total Labor Cost			$ 378
		Cost per Ton			.0164

B. OPERATING & MAINTENANCE SUPPLIES

1. Drill Steel = 2818 ft drilled/wk x $.028 /ft drilled = $ 79
2. Bits = 2818 ft drilled/wk x $.037 /ft drilled = 104
3. Detergent = 2818 ft drilled/wk x $.0005/ft drilled = 1
4. Compressor = 25.8 drilling hrs/wk x $ 6.17/drilling hr = 159
5. Drill Unit & Carrier =
   a) Drilling = 25.8 drilling hrs/wk x $4.80 /drilling hr = 124
   b) Place Change = 1 place change hrs/wk x $3.31 / place change hr = 3
6. Water = 2818ft drilled/wk x .19 gals/ft drilled x $.0005/gal = 1
7. Grinding Wheels = 2818ft drilled/wk x $.001 /ft drilled = 2
8. Miscellaneous (Bits, lube, wrenches, paint, etc.) 11.74 rounds/wk x $2.04 /round = 2

Total Supply Cost $ 475
Cost per Ton .0206

LABOR COST/TON = $0.0270
SUPPLY COST/TON = $0.0206

ESTIMATED TOTAL COST/TON = $0.0476

THE CLEVELAND - CLIFFS IRON CO.
WESTERN DIVISION

PROJECT: JOY DRILLING TEST

LOWER LEVEL MINING - 3,450 TONS/DAY 23,000 TONS/WEEK

MAINTENANCE COST - DRILLING (WET ROTARY)

		COST PER WEEK
A. MAINTENANCE LABOR		
1. Drill Unit & Carrier		
a) Drilling = 25.8 drilling hrs/wk x $ 7.24/drilling hr	=	$ 187
b) Place Change = 1 place change hrs/wk x $ 2.43/place change hr	=	2
2. Compressor = 25.8 drilling hrs/wk x $ 2.20/drilling hr	=	57
Total Labor Cost		$ 246
Cost per Ton		.0106

FIGURE #1

PLOT OF AVERAGE PENETRATION RATES FROM 20 HOLES DRILLED WITH THE SAME BIT

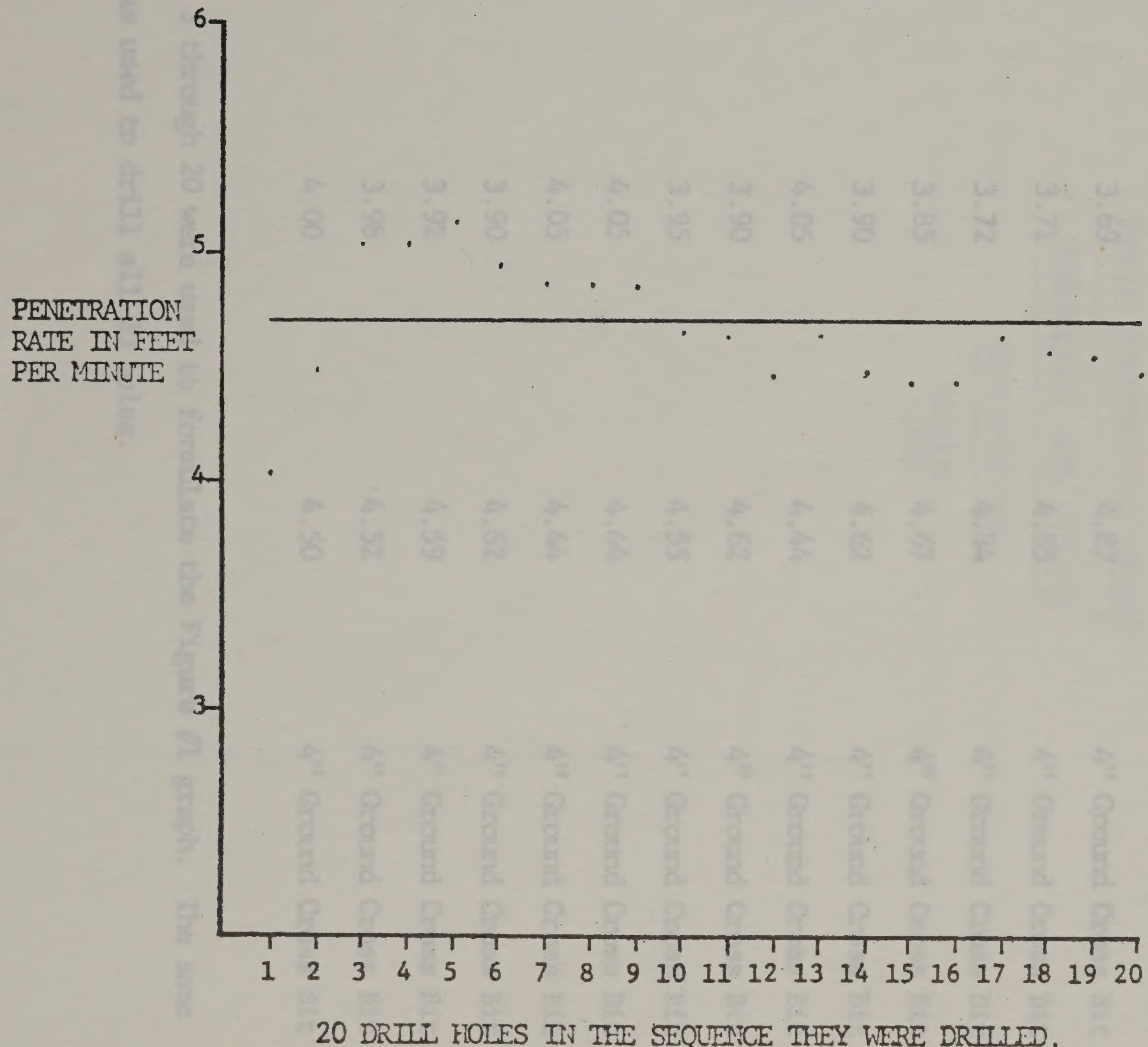


TABLE I

HOLE NUMBER	TIME TO DRILL 18 FEET (MINUTES)	FEET PER MINUTE	BIT
1	5.36	3.35	4" Ground Cross Bit
2	8.10	2.22	4" Button Bit
3	4.45	4.04	4" Ground Cross Bit
4	4.00	4.50	4" Ground Cross Bit
5	3.54	5.08	4" Ground Cross Bit
6	3.54	5.08	4" Ground Cross Bit
7	3.50	5.14	4" Ground Cross Bit
8	3.64	4.94	4" Ground Cross Bit
9	3.69	4.87	4" Ground Cross Bit
10	3.71	4.85	4" Ground Cross Bit
11	3.72	4.84	4" Ground Cross Bit
12	3.85	4.67	4" Ground Cross Bit
13	3.90	4.62	4" Ground Cross Bit
14	4.05	4.44	4" Ground Cross Bit
15	3.90	4.62	4" Ground Cross Bit
16	3.95	4.55	4" Ground Cross Bit
17	4.05	4.44	4" Ground Cross Bit
18	4.05	4.44	4" Ground Cross Bit
19	3.90	4.62	4" Ground Cross Bit
20	3.92	4.59	4" Ground Cross Bit
21	3.98	4.52	4" Ground Cross Bit
22	4.00	4.50	4" Ground Cross Bit

REMARKS: Holes 3 through 20 were used to formulate the Figure #1 graph. The same bit was used to drill all 20 holes.

PARAHO DEMONSTRATION PROJECT

MAN/MACHINE WORK STUDIES

FACE DRILLING

October
1975

PARAHO DEMONSTRATION PROJECT

MAN/MACHINE WORK STUDIES

Anvil Points Mine
Rifle, Colorado

October 1975

PROJECT:

Work Studies - Face Drilling

DESCRIPTION:

Work studies utilizing a break out of elemental times were used to calculate a standard cycle time for face drilling one 26 hole round.

PURPOSE:

Calculate a face drilling cycle (23 hole round) for a commercial size mining operation.

AUTHOR:

W. W. Moulton

PROJECT LOCATION AND FULL FACE DRILLING FUNCTION

This industrial engineering project was performed at the Paraho Demonstration Project's Anvil Points Mine, near Rifle, Colorado. The mine utilizes room and pillar mining for the extraction of oil shale rock. Room dimensions are 55 feet wide and 40 feet high. Figure 1, page 25 is a drawing of the 55' x 40' face, 26 drill hole pattern. The cut holes are approximately 24 feet deep and the other holes are between 20 and 22 feet deep depending upon the face configuration. Each round is expected to pull 20 feet.

EQUIPMENT DESCRIPTION

Face drilling is accomplished using a Gardner-Denver one boom jumbo equipped with a J.E.D.-1 rotary drill. This jumbo is mounted on a Mack 20 ton truck. Figure 3, page 27, is a drawing of the jumbo mounted on the truck.

An electric motor rated at 75 horsepower is used to supply power to run the hydraulic system. Another small electric motor powers the hydraulic fluid cooling system. Air supplied by the mine's air compressor and water are used to clean the hole.

Table I indicates the type and manufacturer of the bits and steel used on the jumbo.

TABLE I

Item	Manufacturer	Size	Remarks
Bits	Gault Tool Co.	4-1/4"	4-wing drag bits
Steel	Gardner-Denver Co.	3"	

STANDARD CYCLE TIME

The face drilling cycle takes place after a heading has been roof bolted. Standard cycle time is the computation of the total time required to drill a 26 hole round. Total time is the summation of the elemental times derived from the timing of cycle elements. Cycle elements for face drilling are as follows:

1. Rig move in - set up and tear down - move out
2. Position and repositioning of boom at the hole location
3. Collaring the hole
4. Drilling the hole
5. Retracting the drill from completed hole
6. Bit change

The above cycle forms the major part of the total work cycle. The other part of the total work cycle is made up of various delays. These delays are noted in the man/machine charts where they occurred in the drilling sequence.

Standard industrial engineering procedures used in this analysis involved the calculation of mean times, standard deviation and percent standard deviation. In order to determine if a sufficient number of element cycles were recorded to allow a confidence level of 95 percent each element cycle was analyzed using the "t" test. This calculation is included on pages 8 to 11.

The man/machine time chart, pages 12 to 23, is a step by step breakdown of cycle element times with a cumulative time summation. This chart is followed by a summary sheet, page 24, which shows the total times, means, standard deviations and percent standard deviations for each cycle element.

ACTUAL WORK CYCLE

CONDITIONS

Floor - Irregular

Face - Irregular

POSSIBLE PRODUCTIVE WORK TIME

(Assume 100% utilization of time)

Allowances:	
Travel to Work	30 Minutes
Travel to Lunch	5 Minutes
Lunch	30 Minutes *
Return to Work	5 Minutes
Supervision	15 Minutes
Personal	15 Minutes
Travel from Mine	30 Minutes
	100 Minutes

* Not paid and not included in total.

Total Work Day

8 hours or 480 minutes 480 - 100 = 380 minutes (possible productive work time)

The actual work cycle times are an accumulation of cycle times from five different rounds. Actual work times will not be included but a total time is included on the man/machine time chart and a cycle element breakdown is included in the summary sheet.

CYCLE ELEMENT (TOTALS)

For a 26 hole round the following numbers are averages taken from the actual work times.

1. Move in - set up - tear down move out (25.56 minutes each)	51.12 Minutes
2. Position and reposition on prospective hole	77.52 Minutes
3. Collar the hole	13.06 Minutes
4. Drill the hole	164.06 Minutes
5. Retract the drill	23.25 Minutes
6. Bit changes (3 occurrences per round)	17.29 Minutes
7. Delays (prorated)	77.53 Minutes
	423.83 Minutes

$\frac{423.83}{26} = 16.30$ minutes to drill one hole

$\frac{380.00}{423.83} = .896$ rounds drilled per day

The drilling element represents 38.17% of the total cycle time and position of the drill on the prospective hole represents 18.3% of the total cycle time. Together they represent 57% of the total time which would indicate a change in machine design. One change would be an increase in the number of drill booms on the jumbo. Delays consume 18.3% of the total cycle time. Forty percent of the 18.3% is spent moving the rig in order to drill holes along either rib. This moving could be eliminated by designing a drilling jumbo that will drill an entire round from one set up. Twelve percent of the 18.3% is spent filling the water tank. This delay could be eliminated by having a holding tank with water capacity for a shift of drilling.

Major breakdowns are to be expected with a drill jumbo the size of the one that will be used in a commercial operation. In order that these breakdowns do not interfere with production, a back up drill jumbo will be required.

PROJECTED FACE DRILLING PROCEDURE FOR A COMMERCIAL OPERATION

In order to attain maximum efficiency in the face drilling function the drill jumbo will be a two boom, completely mobile, self-contained unit It will be a diesel powered, rubber-tired chassis equipped with a compressor, hydraulic pumps and storage for fuel, water and hydraulic fluid. Power for the hydraulic pumps and compressor will be supplied with diesel engines. The following chart will be a work cycle for a drill jumbo equipped with two booms and operated by one man.

A round for a commercial operation will consist of 23 drill holes as shown in Figure 2 on page 26.

WORK CYCLE

(23 Drill Holes)

Face Drilling - 1 operator - 2 drills

ASSUME:

8 hour or 480 minute work day (collar to collar)

ALLOWANCES:

Travel to Work Place	10.00 Minutes
Lunch	30.00 Minutes *
Personal	15.00 Minutes
Supervision	10.00 Minutes
Return to Surface	15.00 Minutes
	80.00 Minutes

* 5 Minutes to Lunch, 20 Minutes Lunch, 5 Minutes to Work

480 - 80 = 400 Minutes (possible productive work time)

23 Drill Hole Work Cycle - (2,900 Tons Produced Rock)

(All Numbers Have Been Projected From Actual Cycle Times)

PROJECTED WORK CYCLE

Prepare rig (fuel, water & service) (30.00 prorated)	7.50 Minutes
Move in - set up	6.60 Minutes
Position and reposition (booms) on prospective hole	17.94 Minutes
Collar the hole	3.19 Minutes
Drill the hole *	38.20 Minutes
Retract the drill	5.69 Minutes
Bit change (2 times) **	3.00 Minutes
Tear down - move out	1.68 Minutes
Delays	17.14 Minutes
	100.95 Minutes

* Based on 6.02 feet per minute

** Utilizing a bit breakout wrench built on each boom

$= \frac{\text{400 Minutes}}{\text{100.95 Minutes}}$ Possible Productive Work Time = 3.96 rounds drilled/8 hour shift at

20 shifts per week = 79.20 rounds drilled per week.

ROTARY DRILLING - GARDNER-DENVER JUMBO 4-1/4" BIT

Position and Reposition Time - All Holes

Calculation to estimate true mean 'M' from sample data.

$\Sigma x = 268.35$

$N = 90$

$\bar{x} = 2.9816$

$\Sigma x^2 = 1049.40$

$$S(x) = \sqrt{\frac{\Sigma x^2 - \bar{x}\,\Sigma x}{N-1}}$$

$$S(x) = \sqrt{\frac{1049.40 - 2.98\ (268.35)}{90-1}}$$

$$S(x) = \sqrt{\frac{1049.40 - 799.68}{89}} = \sqrt{\frac{249.72}{89}} = \sqrt{2.81} = 1.68$$

$$S(\bar{x}) = \frac{S(x)}{\sqrt{N}}$$

$$S(\bar{x}) = \frac{1.68}{\sqrt{90}} = \frac{1.68}{9.4868} = 0.1771$$

M @ 95% Confidence Level

$M = \bar{x} \pm T\ 0.05 \quad s(\bar{x})$

$M = 2.98 \pm 1.99\ (0.1771)$

$M = 2.98 \pm .35$ minutes per hole

ROTARY DRILLING - GARDNER-DENVER JUMBO 4-1/4" BIT

Collaring Time - All Holes

Calculation to estimate true mean "M" from sample data.

$\delta x = 45.21$

$N = 90$

$\bar{x} = .5023$

$\delta x^2 = 28.80$

$$S(x) = \sqrt{\frac{\delta x^2 - \bar{x}\,\delta x}{N-1}}$$

$$S(x) = \sqrt{\frac{28.80 - .50\ (45.2)}{90-1}}$$

$$S(x) = \sqrt{\frac{28.80 - 22.60}{89}} = \sqrt{\frac{6.20}{89}} = \sqrt{.0697} = .264$$

$$S(\bar{x}) = \frac{S(x)}{\sqrt{N}}$$

$$S(\bar{x}) = \frac{.264}{\sqrt{90}} = \frac{.264}{9.4868} = .0278$$

M @ 95% Confidence Level

$M = \bar{x} \pm T\ 0.05\ \ S(\bar{x})$

$M = .5023 \pm 1.990\ (.0278)$

$M = .5023 \pm .0553$ minutes per hole

ROTARY DRILLING - GARDNER-DENVER JUMBO 4-1/4" BIT

Drilling Time - All Holes

Calculation to estimate true mean 'M' from sample data.

$\Sigma x = 586.85$

$N = 93$

$\bar{x} = 6.310$

$\Sigma x^2 = 4089.21$

$$S(x) = \sqrt{\frac{\Sigma x^2 - \bar{x}\,\Sigma x}{N-1}}$$

$$S(x) = \sqrt{\frac{4089.21 - 6.31(586.85)}{93-1}}$$

$$S(x) = \sqrt{\frac{4089.21 - 3703.02}{92}} = \sqrt{\frac{386.19}{92}} = \sqrt{4.1977} = 2.04$$

$$S(\bar{x}) = \frac{S(x)}{\sqrt{N}}$$

$$S(\bar{x}) = \frac{2.04}{\sqrt{93}} = \frac{2.04}{9.643} = .2115$$

M @ 95% Confidence Level

$M = \bar{x} \pm T\ 0.05\ \ S(\bar{x})$

$M = 6.310 \pm 1.9912\ (.2115)$

$M = 6.310 \pm .4211$ minutes per hole = 2.97 to 3.39 ft/minute

ROTARY DRILLING - GARDNER-DENVER JUMBO 4-1/4" BIT

Bit Change Time - All Holes

Calculation to estimate true mean "M" from sample data.

$\Sigma x = 74.92$

$N = 13$

$x = 5.76$

$\Sigma x^2 = 497.57$

$$S(x) = \sqrt{\frac{\Sigma x^2 - x\ \Sigma x}{N-1}}$$

$$S(x) = \sqrt{\frac{497.57 - 5.76\ (74.92)}{13-1}}$$

$$S(x) = \sqrt{\frac{497.57 - 431.54}{12}} = \sqrt{\frac{66.03}{12}} = \sqrt{5.5025} = 2.345$$

$$S(\bar{x}) = \frac{S(x)}{\sqrt{N}}$$

$$S(\bar{x}) = \frac{2.345}{\sqrt{13}} = \frac{2.345}{3.605} = .650$$

M @ 95% Confidence Level

$M = \bar{x} \pm T\ 0.05\ \ S(\bar{x})$

$M = 5.76 \pm 2.160\ \ (.650)$

$M = 5.76 \pm 1.404$ minutes per hole (prorated)

95% confident that $4.356 \leq M \leq 7.164$

MAN/MACHINE TIME CHART

Face Drilling - Anvil Points Mine

October 1975

HOLE NO.	ELEMENT	TIME	CUMULATIVE TIME
	Rig set up	34.82	34.82
1	Position	-	34.82
	Collar hole	.36	35.18
	Drill hole	10.58	45.76
	Retract drill	.67	46.43
2	Reposition	3.13	49.56
	Collar hole	.88	50.44
	Drill hole	6.81	57.25
	Retract drill	.83	58.08
3	Reposition	1.52	59.60
	Collar hole	.84	60.44
	Drill hole	7.57	68.01
	Retract drill	.84	68.85
	DELAY: Lost Paint Mark	9.00	77.85
4	Reposition	1.31	79.16
	Collar hole	.28	79.44
	Drill hole	9.42	88.86
	Retract drill	.87	89.73
	Change bit	4.48	94.21
5	Reposition	6.58	100.79
	Collar hole	.92	101.71
	Drill hole	9.02	110.73
	Retract drill	.69	111.42
6	Reposition	6.16	117.58
	Collar hole	1.00	118.58
	Drill hole	5.48	124.06
	Retract drill	1.18	125.24
7	Reposition	5.74	130.98
	Collar hole	1.28	132.26
	Drill hole	6.00	138.26
	Retract drill	.69	138.95
8	Reposition	5.88	144.83
	Collar hole	1.02	145.85
	Drill hole	4.18	150.03
	Retract drill	1.02	151.05

MAN/MACHINE TIME CHART

Face Drilling - Anvil Points Mine

October 1975

HOLE NO.	ELEMENT	TIME	CUMULATIVE TIME
9	Reposition	3.24	154.29
	Collar hole	1.44	155.73
	Drill hole	5.28	161.01
	Retract drill	.88	161.89
	Change bit	4.80	166.69
	DELAY: Lost bit wrench	8.00	174.69
10	Reposition	5.94	180.63
	Collar hole	.97	181.60
	Drill hole	11.15	192.75
	Retract drill	.82	193.57
11	Reposition	5.15	198.72
	Collar hole	.94	199.66
	Drill hole	10.42	210.08
	Retract drill	1.08	211.16
	DELAY: Fill water tank	8.52	219.68
12	Reposition	5.78	225.46
	Collar hole	-	225.46
	Drill hole	4.86	230.32
	Retract drill	.78	231.10
13	Reposition	7.80	238.90
	Collar hole	.47	239.37
	Drill hole	6.01	245.38
	Retract drill	.82	246.20
14	Reposition	3.40	249.60
	Collar hole	.97	250.57
	Drill hole	9.33	259.90
	Retract drill	1.29	261.19
	DELAY: Move rig	32.03	293.22
15	Reposition	-	293.22
	Collar hole	.48	293.70
	Drill hole	5.04	298.74
	Retract drill	.91	299.65
16	Reposition	3.84	303.49
	Collar hole	.67	304.16
	Drill hole	5.25	309.41
	Retract drill	.88	310.29

MAN/MACHINE TIME CHART

Face Drilling - Anvil Points Mine

October 1975

HOLE NO.	ELEMENT	TIME	CUMULATIVE TIME
17	Reposition	2.33	312.62
	Collar hole	.58	313.20
	Drill hole	4.00	317.20
	Retract drill	.98	318.18
18	Reposition	3.41	321.59
	Collar hole	.92	322.51
	Drill hole	5.96	328.47
	Retract drill	.91	329.38
19	Reposition	3.18	332.56
	Collar hole	.42	332.98
	Drill hole	3.62	336.60
	Retract drill	.73	337.33
20	Reposition	4.18	341.51
	Collar hole	.32	341.83
	Drill hole	5.04	346.87
	Change bit	5.22	352.09
	Retract drill	.92	353.01
21	Reposition	1.32	354.33
	Collar hole	.41	354.74
	Drill hole	6.63	361.37
	Retract drill	1.00	362.37
22	Reposition	1.26	363.63
	Collar hole	.52	364.15
	Drill hole	4.55	368.70
	Retract drill	1.32	370.02
23	Reposition	1.42	371.44
	Collar hole	.32	371.76
	Drill hole	4.45	376.21
	Retract drill	.85	377.06
24	Reposition	3.74	380.80
	Collar hole	.31	381.11
	Drill hole	12.36	393.47
	Retract drill	.78	394.25

MAN/MACHINE TIME CHART

Face Drilling - Anvil Points Mine

October 1975

HOLE NO.	ELEMENT	TIME	CUMULATIVE TIME
25	Reposition	4.21	398.46
	Collar hole	-	398.46
	Drill hole	11.31	409.77
	Retract drill	.72	410.49
	DELAY: Plugged air screen	25.00	435.49
26	Reposition	6.90	442.39
	Collar hole	.35	442.74
	Drill hole	4.73	447.47
	Retract drill	1.05	448.52
27	Reposition	1.41	449.93
	Collar hole	.32	450.25
	Drill hole	5.70	455.95
	Retract drill	.73	456.68
	Bit change	12.09	468.77
	DELAY: Personal	10.00	478.77
28	Reposition	2.00	480.77
	Collar hole	.34	481.11
	Drill hole	7.25	488.36
	Retract drill	.64	489.00
29	Reposition	5.65	494.65
	Collar hole	.48	495.13
	Drill hole	5.32	500.45
	Retract drill	.68	501.13
30	Reposition	1.42	502.55
	Collar hole	1.10	503.65
	Drill hole	6.92	510.57
	Retract drill	.92	511.49
	DELAY: Move rig	24.32	535.81
31	Reposition	4.21	540.02
	Collar hole	.79	540.81
	Drill hole	10.22	551.03
	Retract drill	1.09	552.12
32	Reposition	2.20	554.32
	Collar hole	.84	555.16
	Drill hole	9.88	565.04
	Retract drill	.77	565.81
	DELAY: Repair hydraulic leaks	55.00	620.81

MAN/MACHINE TIME CHART

Face Drilling - Anvil Points Mine

October 1975

HOLE NO.	ELEMENT	TIME	CUMULATIVE TIME
33	Reposition	5.73	626.54
	Collar hole	.56	627.10
	Drill hole	6.60	633.70
	Retract drill	.58	634.28
34	Reposition	2.01	636.29
	Collar hole	.75	637.04
	Drill hole	5.49	642.53
	Retract drill	.54	643.07
35	Reposition	1.64	644.71
	Collar hole	.62	645.33
	Drill hole	6.93	652.26
	Retract drill	.45	652.71
36	Reposition	2.89	655.60
	Collar hole	.51	656.11
	Drill hole	5.56	661.67
	Retract drill	.81	662.48
37	Reposition	2.29	664.77
	Collar hole	.61	665.38
	Drill hole	3.59	668.97
	Retract drill	.56	669.53
38	Reposition	3.18	672.71
	Collar hole	.62	673.33
	Drill hole	7.10	680.43
	Retract drill	.72	681.15
39	Reposition	3.30	684.45
	Collar hole	1.02	685.47
	Drill hole	6.07	691.54
	Retract drill	1.00	692.54
40	Reposition	5.00	697.54
	Collar hole	.68	698.22
	Drill hole	6.60	704.82
	Retract drill	.78	705.60
41	Reposition	1.55	707.15
	Collar hole	.70	707.85
	Drill hole	7.30	715.15
	Retract drill	.68	715.83
	DELAY: Repair hydraulic leaks	30.00	745.83

MAN/MACHINE TIME CHART

Face Drilling - Anvil Points Mine

October 1975

HOLE NO.	ELEMENT	TIME	CUMULATIVE TIME
42	Reposition	5.26	751.09
	Collar hole	.72	751.81
	Drill hole	7.50	759.31
	Retract drill	.64	759.95
	Change bit	9.20	769.15
	DELAY: Lost air clean screen	20.00	789.15
43	Reposition	2.35	791.50
	Collar hole	.94	792.44
	Drill hole	5.65	798.09
	Retract drill	.52	798.61
44	Reposition	2.47	801.08
	Collar hole	.78	801.86
	Drill hole	6.21	808.07
	Retract drill	.76	808.83
45	Reposition	.94	809.77
	Collar hole	.44	810.21
	Drill hole	6.22	816.43
	Retract drill	1.05	817.48
46	Reposition	.88	818.36
	Collar hole	.36	818.72
	Drill hole	6.65	825.37
	Retract drill	1.11	826.48
	DELAY: Move rig	54.84	881.32
	DELAY: Personal	6.64	887.96
47	Reposition	1.04	889.00
	Collar hole	.36	889.36
	Drill hole	4.88	894.24
	Retract drill	.78	895.02
	Bit change	4.15	899.17
48	Reposition	2.44	901.61
	Collar hole	.40	902.01
	Drill hole	5.89	907.90
	Retract drill	.98	908.88
49	Reposition	1.05	909.93
	Collar hole	.36	910.29
	Drill hole	6.05	916.34
	Retract drill	1.02	917.36

MAN/MACHINE TIME CHART

Face Drilling - Anvil Points Mine

October 1975

HOLE NO.	ELEMENT	TIME	CUMULATIVE TIME
50	Reposition	1.80	919.16
	Collar hole	1.80	919.50
	Drill hole	7.71	927.21
	Retract drill	.95	928.16
51	Reposition	1.75	929.91
	Collar hole	.35	930.26
	Drill hole	6.53	936.79
	Retract drill	.89	937.68
52	Reposition	2.09	939.77
	Collar hole	.37	940.14
	Drill hole	9.02	949.16
	Retract drill	.88	950.04
	DELAY: Reposition rig	6.10	956.14
53	Reposition	3.57	959.71
	Collar hole	.32	960.03
	Drill hole	5.32	965.35
	Retract drill	.88	966.23
	Lunch	54.38	1020.61
	Bit change	3.89	1024.50
54	Reposition	1.99	1026.49
	Collar hole	.33	1026.82
	Drill hole	4.47	1031.29
	Retract drill	1.04	1032.33
55	Reposition	2.92	1035.25
	Collar hole	.33	1035.58
	Drill hole	6.60	1042.18
	Retract drill	1.01	1043.19
56	Reposition	3.00	1046.19
	Collar hole	.34	1046.53
	Drill hole	6.92	1053.45
	Retract drill	1.03	1054.48
	Tear down - move out	17.22	1071.70

MAN/MACHINE TIME CHART

Face Drilling - Anvil Points Mine

October 1975

HOLE NO.	ELEMENT	TIME	CUMULATIVE TIME
57	Reposition	2.59	1074.29
	Collar hole	.28	1074.57
	Drill hole	6.76	1081.33
	Retract drill	.83	1082.16
	Bit change	4.32	1086.48
58	Reposition	1.58	1088.06
	Collar hole	.25	1088.31
	Drill hole	4.24	1092.55
	Retract drill	.88	1093.43
59	Reposition	1.85	1095.28
	Collar hole	.28	1095.56
	Drill hole	5.28	1100.84
	Retract drill	.75	1101.59
60	Reposition	2.20	1103.79
	Collar hole	.27	1104.06
	Drill hole	8.20	1112.26
	Retract drill	.79	1113.05
61	Reposition	1.30	1114.35
	Collar hole	.25	1114.60
	Drill hole	6.24	1120.84
	Retract drill	.84	1121.68
62	Reposition	1.65	1123.33
	Collar hole	.55	1123.88
	Drill hole	11.13	1135.01
	Retract drill	.87	1135.88
	Bit change	5.08	1140.96
	DELAY: Fill water tank	5.42	1146.38
	DELAY: Personal	2.56	1148.94
63	Reposition	5.10	1154.04
	Collar hole	.26	1154.30
	Drill hole	5.51	1159.81
	Retract drill	.88	1160.69
64	Reposition	1.91	1162.60
	Collar hole	.64	1163.24
	Drill hole	7.65	1170.89
	Retract drill	.87	1171.76
	DELAY: Move truck	28.00	1199.76

MAN/MACHINE TIME CHART

Face Drilling - Anvil Points Mine

October 1975

HOLE NO.	ELEMENT	TIME	CUMULATIVE TIME
65	Reposition	3.38	1203.14
	Collar hole	.29	1203.43
	Drill hole	5.58	1209.01
	Retract drill	-	1209.01
66	Reposition	-	1209.01
	Collar hole	.28	1209.29
	Drill hole	5.72	1215.01
	Retract drill	.92	1215.93
67	Reposition	1.75	1217.68
	Collar hole	.23	1217.91
	Drill hole	4.41	1222.32
	Retract drill	.90	1223.22
68	Reposition	4.00	1227.22
	Collar hole	.27	1227.49
	Drill hole	4.40	1231.89
	Retract drill	.88	1232.77
69	Reposition	3.42	1236.19
	Collar hole	.24	1236.43
	Drill hole	4.35	1240.78
	Retract drill	.92	1241.70
70	Reposition	3.88	1245.58
	Collar hole	.25	1245.83
	Drill hole	3.30	1249.13
	Retract drill	1.02	1250.15
71	Reposition	2.35	1252.50
	Collar hole	.30	1252.80
	Drill hole	4.25	1257.05
	Retract drill	1.10	1258.15
72	Reposition	3.05	1261.20
	Collar hole	.25	1261.45
	Drill hole	5.25	1266.70
	Retract drill	1.05	1267.75
	Bit change	4.35	1272.10
73	Reposition	3.12	1275.22
	Collar hole	.30	1275.52
	Drill hole	4.82	1280.34
	Retract drill	.92	1281.26

MAN/MACHINE TIME CHART

Face Drilling - Anvil Points Mine

October 1975

HOLE NO.	ELEMENT	TIME	CUMULATIVE TIME
74	Reposition	1.06	1282.32
	Collar hole	.26	1282.58
	Drill hole	5.58	1288.16
	Retract drill	.99	1289.15
75	Reposition	1.32	1290.47
	Collar hole	.36	1290.83
	Drill hole	5.62	1296.45
	Retract drill	1.12	1297.57
76	Reposition	4.14	1301.71
	Collar hole	.29	1302.00
	DELAY: Fill water tank	23.70	1325.70
	Bit change	5.23	1330.93
	Drill hole	5.34	1336.27
	Retract drill	.95	1337.22
	Lunch	60.00	1397.22
77	Reposition	7.40	1404.62
	Collar hole	.38	1405.00
	Drill hole	6.99	1411.99
	Retract drill	.95	1412.94
	Tear down move out	27.20	1440.14
	Move in - set up	23.01	1463.15
78	Reposition	5.90	1469.05
	Collar hole	.38	1469.43
	Drill hole	4.50	1473.93
	Retract drill	1.00	1474.93
79	Reposition	1.92	1476.85
	Collar hole	.39	1477.24
	Drill hole	4.34	1481.58
	Retract drill	1.04	1482.62
80	Reposition	1.82	1484.44
	Collar hole	.42	1484.86
	Drill hole	4.00	1488.86
	Retract drill	1.02	1489.88
81	Reposition	3.32	1493.20
	Collar hole	.26	1493.46
	Drill hole	3.83	1497.29
	Retract drill	1.05	1498.34

MAN/MACHINE TIME CHART

Face Drilling - Anvil Points Mine

October 1975

HOLE NO.	ELEMENT	TIME	CUMULATIVE TIME
82	Reposition	2.26	1500.60
	Collar hole	.34	1500.94
	Drill hole	3.65	1504.59
	Retract drill	1.00	1505.59
83	Reposition	3.05	1508.64
	Collar hole	.36	1509.00
	Drill hole	10.75	1519.75
	Retract drill	1.10	1520.85
	Bit change	6.07	1526.92
	DELAY: Fill water tank	6.47	1533.39
84	Reposition	2.55	1535.94
	Collar hole	-	1535.94
	Drill hole	8.50	1544.44
	Retract drill	.94	1545.38
85	Reposition	1.20	1546.58
	Collar hole	.44	1547.02
	Drill hole	6.00	1553.02
	Retract drill	.97	1553.99
86	Reposition	3.34	1557.33
	Collar hole	.30	1557.63
	Drill hole	3.35	1560.98
	Retract drill	.89	1561.87
87	Reposition	.84	1562.71
	Collar hole	.30	1563.01
	Drill hole	3.58	1566.59
	Retract drill	.88	1567.47
88	Reposition	3.62	1571.09
	Collar hole	.40	1571.49
	Drill hole	5.35	1576.84
	Retract drill	.94	1577.78
	Bit change	6.04	1583.82
	DELAY: Plugged water line	3.30	1587.12
89	Reposition	1.15	1588.27
	Collar hole	.37	1588.64
	Drill hole	4.24	1592.88
	Retract drill	1.06	1593.94

MAN/MACHINE TIME CHART

Face Drilling - Anvil Points Mine

October 1975

HOLE NO.	ELEMENT	TIME	CUMULATIVE TIME
90	Reposition	1.75	1595.69
	Collar hole	.31	1596.00
	Drill hole	6.66	1602.66
	Retract drill	1.08	1603.74
91	Reposition	.90	1604.64
	Collar hole	.37	1605.01
	Drill Hole	6.54	1611.55
	Retract drill	1.05	1612.60
92	Reposition	1.18	1613.78
	Collar hole	.35	1614.13
	Drill hole	7.82	6121.95
	Retract drill	.93	1622.88
93	Reposition	1.05	1623.93
	Collar hole	.39	1624.32
	Drill hole	7.92	1632.24
	Retract drill	-	1632.24

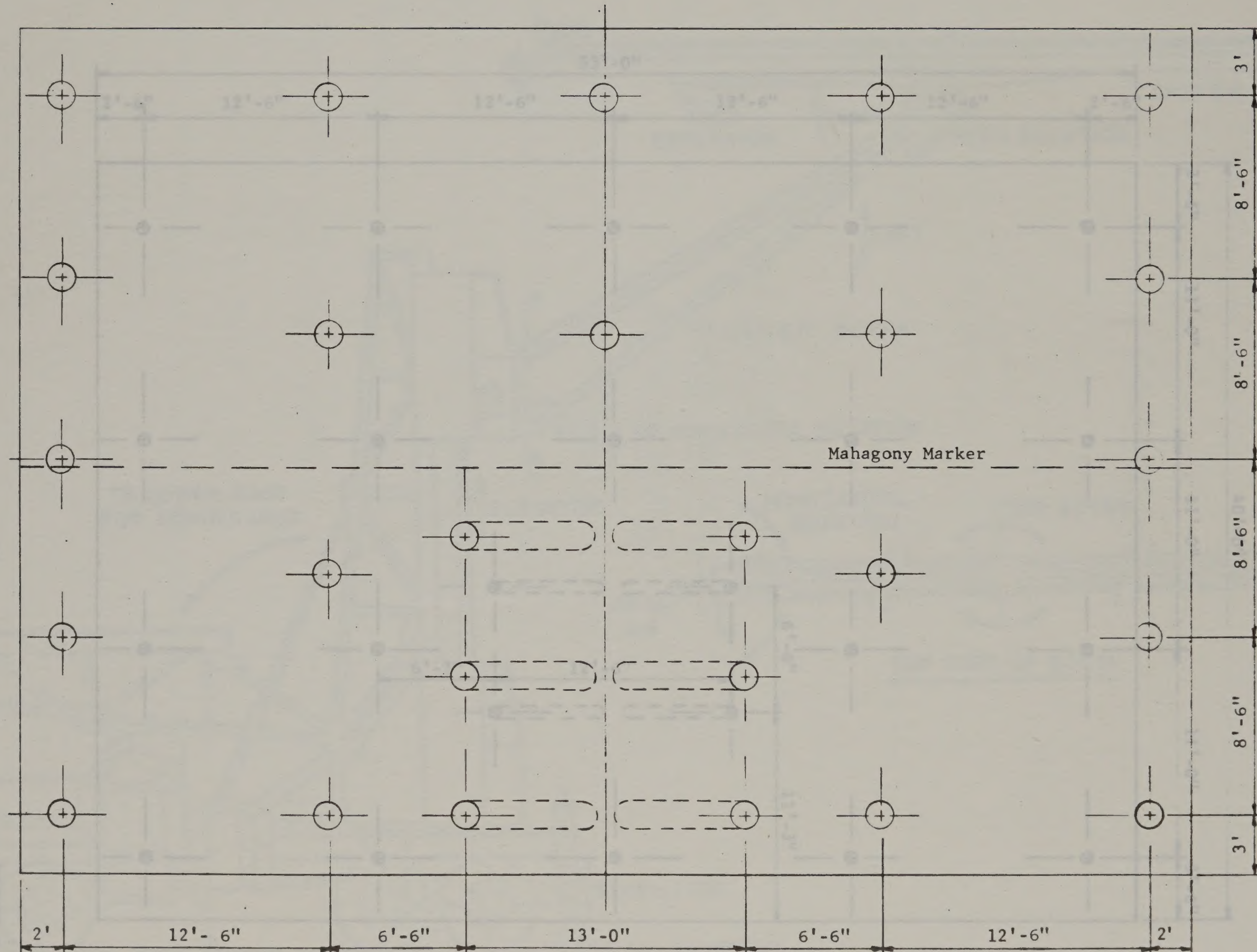
MAN/MACHINE TIME CHART

Face Drilling - Anvil Points Mine

October 1975

SUMMARY SHEET

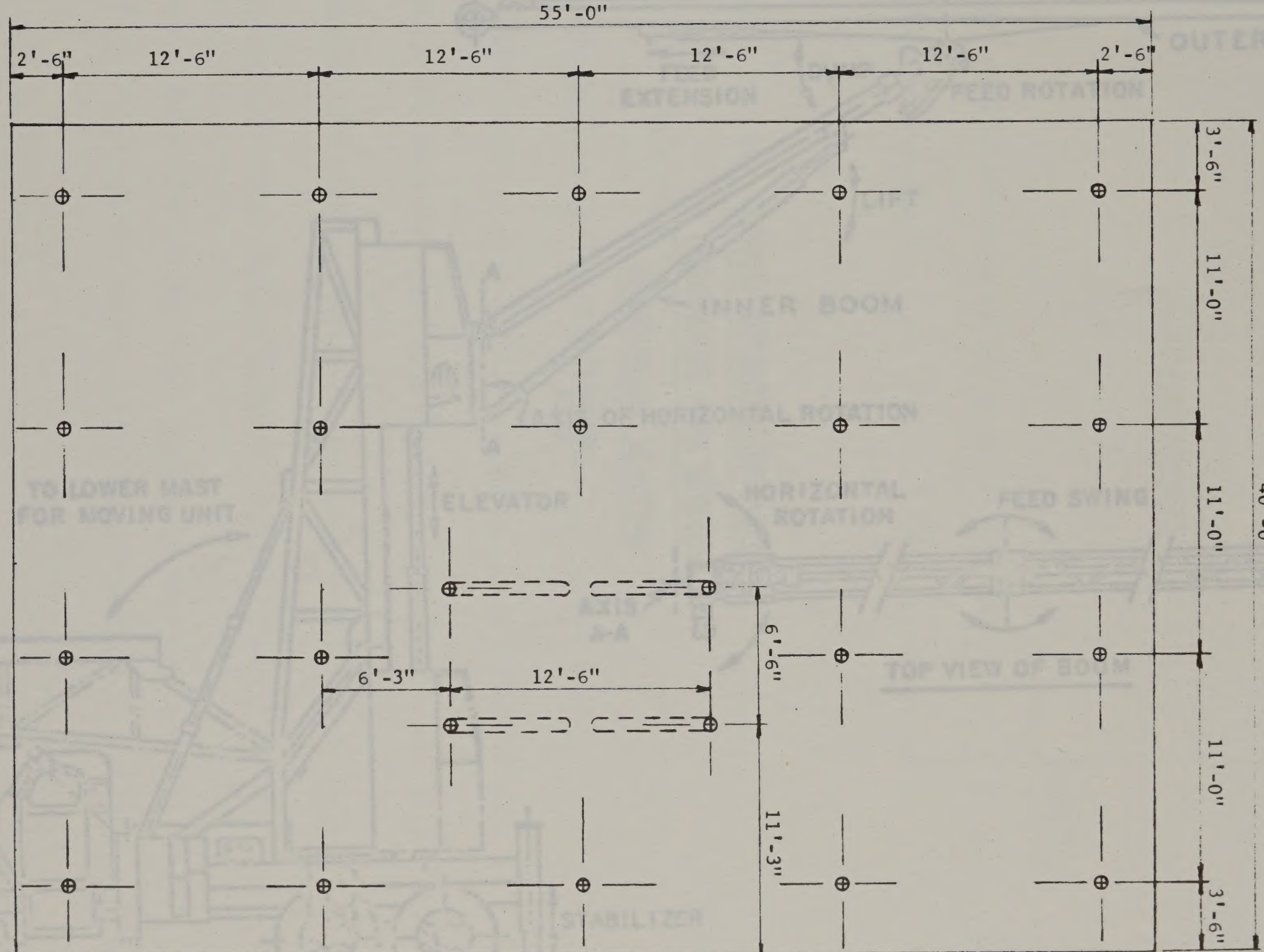
Element	Total Time	Occurrences of Cycle Elements	Mean	Standard Deviation	Per Cent Standard Deviation
1. Move in - set up - tear down - move out	102.25	4	25.56	7.40	29%
2. Position and reposition on prospective hole	268.35	90	2.98	1.70	57%
3. Collar the hole	45.21	90	.50	.27	53%
4. Drill the hole	586.85	93	6.31	2.05	32%
5. Retract the drill	81.38	91	.89	.16	18%
6. Bit change	74.92	13	5.76	2.34	40%
7. Delays	358.90	18	19.38	-	-
8. Lunch	114.38	2	57.19	-	-
	1,632.24				



26 DRILL HOLE PATTERN

FIGURE 1

FIGURE 2



PROJECTED COMMERCIAL DRILL HOLE PATTERN (23 HOLES)

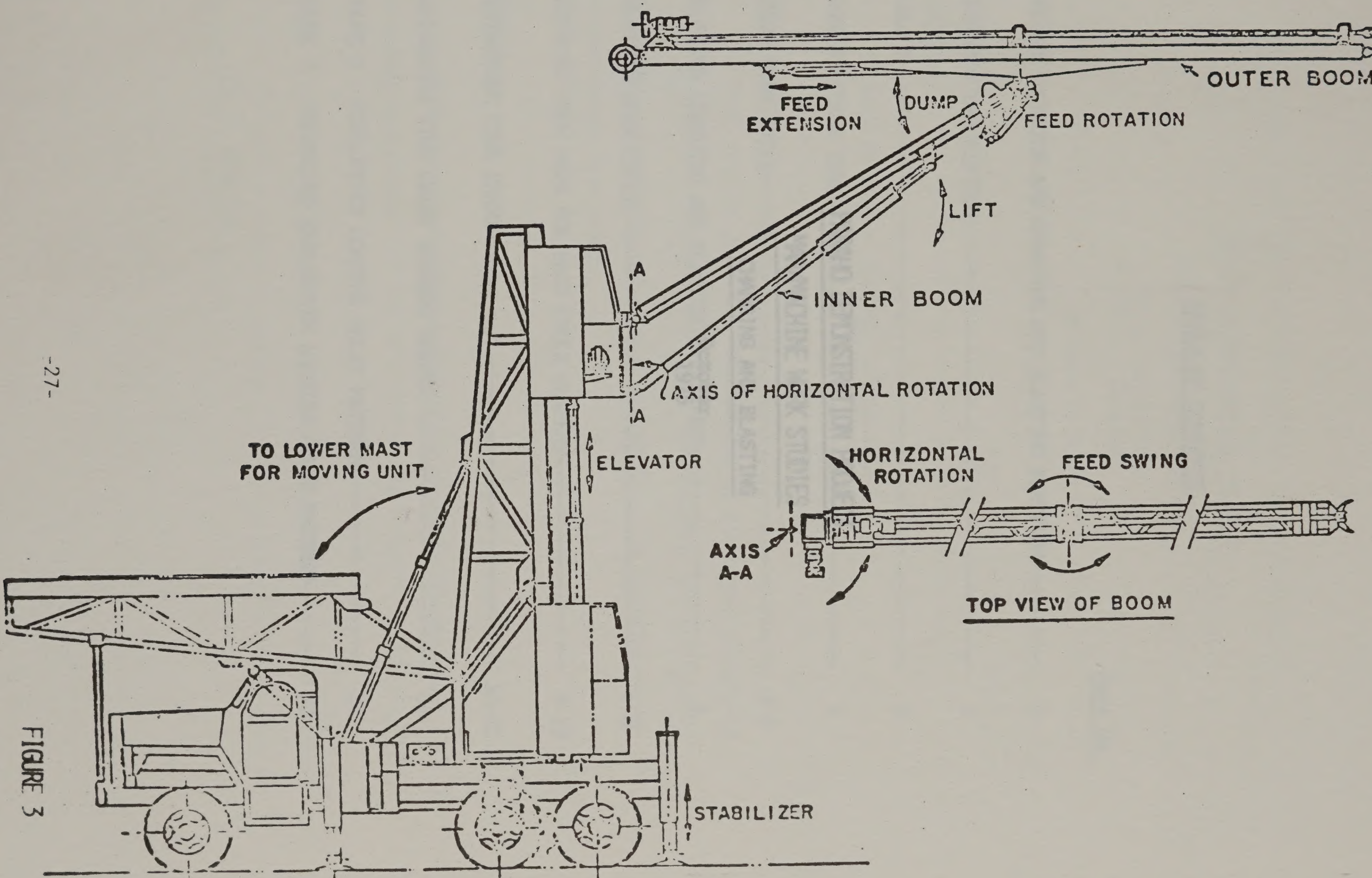


FIGURE 3

1 BOOM JUMBO

PARAHO DEMONSTRATION PROJECT

MAN/MACHINE WORK STUDIES

CHARGING AND BLASTING

October
1975

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PARAHO DEMONSTRATION PROJECT

MAN/MACHINE WORK STUDIES

Anvil Points Mine
Rifle, Colorado

October 1975

PROJECT:

Work Studies - Charging and Blasting

DESCRIPTION:

Work studies utilizing a break out of elemental times were used to calculate a standard cycle time for charging and blasting 26 drill holes. Twenty-six drill holes are used in the blasting of one standard twenty foot round.

PURPOSE:

Calculate a charging and blasting cycle for a commercial size mining operation.

AUTHOR:

W. W. Moulton

PROJECT LOCATION AND CHARGING AND BLASTING FUNCTION

This industrial engineering project was performed at the Paraho Demonstration Project's Anvil Points Mine near Rifle, Colorado. The mine utilizes room and pillar mining for the extraction of oil shale rock. Room dimensions are 55 feet wide by 40 feet high. Each round is designed and drilled to advance twenty feet and produce approximately 2,942 tons of oil shale rock. AN/FO, a mixture of ammonium nitrate and fuel oil is used as the principal blasting agent.

EQUIPMENT DESCRIPTION

Explosives loading is accomplished by means of an aerial platform mounted on a diesel powered carrier (powder monkey). The carrier is equipped with an air injection system which is used to place ammonium nitrate (prills) explosive into drill holes. The air injection system is equipped with a forty foot, two inch flexible hose for the actual loading cycle.

The "powder monkey" is not a self-contained unit. It has to be hooked up the mine's compressed air system for its injection power. Drawbacks in this unit which curtail efficiency are its lack of adequate storage for explosives and its inadequate range regarding the loading of drill holes.

Table I indicates the type and manufacturer of the explosives, primers, delay detonators, prima-cord, fuse and other equipment used in the explosives loading cycle.

TABLE I

Item	Manufacturer	Trade Name	Remarks
Explosives	Du Pont	AN/FO	Mixture of Ammonium Nitrate & Fuel Oil - 50 lb. sacks
Primer	Trojan	Primer Cans	
Delay Detonators	Ensign Bickford Co.	Primadets	
Prima-Cord	Du Pont	E-Cord	
Detonator	Du Pont	Blasting Caps	

STANDARD CYCLE TIME

The explosives loading function takes place after the face drilling function.

Standard cycle time is the computation of the total time required to load and tie in the explosives in a twenty-six hole full face twenty foot round. Total time is the summation of elemental times derived from the timing of cycle elements. Cycle elements for the explosives loading function are as follows:

1. get powder
2. move in - set up - tear down - move out
3. position and reposition on drill hole
4. prepare primer
5. install primer in hole
6. load explosives into drill hole
7. tie in the primer
8. fill explosives holding tank
9. tie in entire round

The above cycle elements form the major portion of the total work cycle. The remaining portion of the total work cycle is made up of various delays. These delays are noted in the man/machine time charts where they occurred in the loading sequence.

Standard industrial engineering procedures used in this analysis included calculation of mean times, standard deviation and per cent standard deviation. In order to determine if a sufficient number of element cycles were recorded to allow a confidence level of 95% each element cycle was analyzed using the "t" test. This calculation is included on pages 9 to 13.

The man/machine time chart, pages 14 to 22, is a step by step breakdown of cycle element times with a cumulative time summation. This chart is followed by a summary sheet, page 23, which shows the total time, mean, standard deviation and percent standard deviation for each cycle element.

ACTUAL WORK CYCLE

Charging and Blasting - 2 men

CONDITIONS:

Floor - Irregular

Back - Smooth

Face and Ribs - Normal (scaled)

POSSIBLE PRODUCTIVE WORK TIME

(Assume 100% utilization of available time)

Allowances:

Travel to Work	30 Minutes
Travel to Lunch	5 Minutes
Lunch	30 Minutes *
Return to Work	5 Minutes
Supervision	15 Minutes
Personal	15 Minutes
Travel from Mine	30 Minutes
	100 Minutes

* Not Paid and Not Included in Total

Total Work Day - 8 hours or 480 minutes = 480 - 100 = 380 minutes (possible productive work time)

Actual Work Times - as segments of three charging and blasting sequences are included in this report the actual working times will not be included. A total work time in minutes is included.

CYCLE ELEMENT (TOTALS):

Charging and blasting sequence - one 26 hole round (all times projected from actual cycle times).

1. Get powder from magazine	36.79 Minutes
2. Move in, set up, tear down, move out	34.58 Minutes
3. Position - reposition	45.50 Minutes
4. Prepare primer	18.05 Minutes
5. Install primer	17.68 Minutes
6. Load explosive into hole	70.72 Minutes
7. Tie in primer	16.38 Minutes

8.	Tie in round	7.00 Minutes
9.	Fill explosives holding tank (3 times)	17.52 Minutes
		264.22 Minutes
	Lunch (10 minutes paid)*	40.00 Minutes
	Delays	42.56 Minutes
		346.78 Minutes
	(Minus 30 minute not paid lunch)	30.00 Minutes
		316.78 Minutes

*Travel Time

$$\frac{316.78}{26} = 12.18 \text{ minutes/hole}$$

$$\frac{380.00}{316.78} = 1.199 \text{ rounds charged and blasted per day or } 5.995 \text{ rounds/week}$$

The amount of powder used in this round was forty-five 50-lb. bags or 2,250 pounds of AN/FO, plus 75 pounds of primer or 2,325 pounds total. The amount of broken rock was estimated at 2,942 tons which equals a powder factor of .764 pounds AN/FO per ton of rock.

In the charging and blasting sequence 53.7 per cent of the total time is consumed in four cycle elements. These elements are:

1. Get powder from magazine
2. Position and reposition explosive injection hose
3. Load explosives into the hole
4. Fill the explosives holding tank.

The injection rate for AN/FO is approximately 25 pounds per minute. The design of the powder monkey could greatly reduce the total time consumed by the four above elements. Delays in the work cycle accounted for 13.4 per cent of the total sequence time. This time could be reduced with a self-contained powder monkey.

PROJECTED CHARGING AND BLASTING PROCEDURE

FOR A COMMERCIAL OPERATION

In order to attain maximum efficiency in the charging and blasting function the powder monkey will be a completely mobile, self-contained unit. It will be a diesel powered carrier equipped with an aerial platform capable of reaching any location on the face from one setup position. This would eliminate moving the truck during the charging sequence. The carrier will be equipped with a self-contained air injection system capable of injecting 150 pounds of explosives per minute and an explosives holding capacity of 7,000 pounds. This will be sufficient explosives for an eight hour shift and enough to load four rounds. These numbers are based on a round with dimensions of 55 feet wide by 40 feet high and a depth of 20 feet. At 14.957 cubic feet per ton of in-place oil shale rock one round will produce approximately 2,942 tons. With a powder factor of .56 pounds AN/FO per ton of produced rock one round will require approximately 1,650 pounds of explosives.

PROJECTED WORK CYCLE
CHARGING AND BLASTING

In projecting a 23 hole work cycle for a commercial operation certain factors were considered. Two of these factors are, the charging unit would be self-contained and the men assigned would perform only the charging and blasting functions.

PREPARE EQUIPMENT FOR WORKDAY - 20.00 MINUTES - LOAD EXPLOSIVE, APPROXIMATELY 7,000 LBS. - SERVICE EQUIPMENT

	Average Time	Total Time 23 Hole Round
Move In	-	2.00 Minutes
Set Up	-	4.00 Minutes
Position and Reposition on Prospective Hole	.59	13.57 Minutes
Prepare Primer	.40	9.20 Minutes
Install Primer	.43	9.89 Minutes
Load Explosives in Hole	.48*	11.04 Minutes
Tie in Primer	.51	11.73 Minutes
Tie in Round	-	2.00 Minutes
Delays	-	8.00 Minutes
Prepare & Service Equipment For Work	Prorated	4.00 Minutes
Tear Down	-	4.00 Minutes
TOTAL		79.43 Minutes

*Based on an AN/FO injection rate of 150 pounds per minute.

PROJECTED WORK CYCLE

CHARGING AND BLASTING

Assume:

8 hour or 480 minute workday (collar to collar)

Allowances:

Travel to work place	10.00 Minutes
Lunch	30.00 Minutes *
Personal	15.00 Minutes
Supervision	10.00 Minutes
Return to Surface	15.00 Minutes
TOTAL	80.00 Minutes

* Lunch Breakdown

5 Minutes to Lunch Room

20 Minutes Lunch

5 Minutes to Return to Work

30 Minutes

480 - 80 = 400 minutes (possible productive work time)

$\frac{400}{79.43}$ = 5.03 rounds charged and blasted per eight hour shift = 100.60 rounds/week

Calculation to estimate true mean (M) from sample data.

$\Sigma x = 96.25$

$N = 55$

$\bar{x} = 1.75$

$\Sigma x^2 = 248.60$

$$S(x) = \sqrt{\frac{\Sigma x^2 - \bar{x}\,\Sigma x}{N-1}} \qquad \frac{(\Sigma x_i)^2}{n} = \frac{\Sigma x_i}{n}\,\Sigma x_i = \bar{x}\,\Sigma x_i$$

$$S(x) = \sqrt{\frac{248.60 - 1.75\ (96.25)}{55 - 1}}$$

$$S(x) = \sqrt{\frac{248.60 - 168.44}{54}} = \sqrt{\frac{80.16}{54}} = \sqrt{1.48} = 1.22$$

$$S(\bar{x}) = \frac{S(x)}{\sqrt{N}}$$

$$S(\bar{x}) = \frac{1.22}{\sqrt{55}} = \frac{1.22}{7.42} = 0.16$$

M @ 95% Confidence Level

$M = \bar{x} \pm T\ 0.05\ \ S(\bar{x})$

$M = 1.75 \ \pm 2.005\ (0.16)$

$M = 1.75 \pm .32$ minutes

EXPLOSIVES LOADING - PREPARING THE PRIMER

Calculation to estimate true mean (M) from sample data.

$$\delta x = 31.47$$

$$N = 46$$

$$\bar{x} = 0.69$$

$$\delta x^2 = 30.28$$

$$S(x) = \sqrt{\frac{\delta x^2 - \bar{x}\ \delta x}{N-1}}$$

$$S(x) = \sqrt{\frac{30.28 - 0.69\ (31.47)}{46 - 1}}$$

$$S(x) = \sqrt{\frac{30.28 - 21.71}{45}} = \sqrt{\frac{8.57}{45}} = \sqrt{0.19} = 0.44$$

$$S(\bar{x}) = \frac{S(x)}{\sqrt{N}}$$

$$S(\bar{x}) = \frac{0.44}{\sqrt{46}} = \frac{0.44}{6.78} = 0.06$$

M @ 95% Confidence Level

$$M = \bar{x} \pm T\ 0.05 \quad s(\bar{x})$$

$$M = 0.69 \pm 2.014\ (0.06)$$

$$M = 0.69 \pm .12 \text{ minutes}$$

Calculation to estimate true mean (M) from sample data.

$\Sigma x = 38.76$

$N = 57$

$\bar{x} \quad 0.68$

$\Sigma x^2 = 32.50$

$$S(x) = \sqrt{\frac{\Sigma x^2 - \bar{x}\,\Sigma x}{N-1}}$$

$$S(x) = \sqrt{\frac{32.50 - .68\ (38.76)}{57-1}}$$

$$S(x) = \sqrt{\frac{32.50 - 26.36}{56}} = \sqrt{\frac{6.14}{56}} = \sqrt{0.11} = 0.33$$

$$S(\bar{x}) = \frac{S(x)}{\sqrt{N}}$$

$$S(\bar{x}) = \frac{0.33}{\sqrt{57}} = \frac{0.33}{7.55} = 0.04$$

M @ 95% Confidence Level

$M = \bar{x} \pm T\ 0.05 \quad S(\bar{x})$

$M = 0.68 \pm 2.003 \quad (.04)$

$M = 0.68 \pm .08$ minutes

Calculation to estimate true mean (M) from sample data.

$$\Sigma x = 154.47$$

$$N = 57$$

$$\bar{x} = 2.72$$

$$\Sigma x^2 = 466.88$$

$$S(x) = \sqrt{\frac{\Sigma x^2 - \bar{x}\ \Sigma x}{N-1}}$$

$$S(x) = \sqrt{\frac{466.88 - 2.72\ (154.47)}{57-1}}$$

$$S(x) = \sqrt{\frac{466.88 - 420.15}{56}} = \sqrt{\frac{46.73}{56}} = \sqrt{.83} = 0.913$$

$$S(\bar{x}) = \frac{S(x)}{\sqrt{N}}$$

$$S(\bar{x}) = \frac{0.913}{\sqrt{57}} = \frac{0.913}{7.55} = 0.12$$

M @ 95% Confidence Level

$M = \bar{x} \pm T0.05\ \ S(\bar{x})$

$M = 2.72 \pm 2.003\ (0.12)$

$M = 2.72 \pm 0.24$ minutes

EXPLOSIVES LOADING - TIE IN PRIMER

Calculation to estimate true mean (M) from sample data.

$$\Sigma x = 35.91$$

$$N = 49$$

$$\bar{x} = 0.63$$

$$\Sigma x^2 = 29.64$$

$$S(x) = \sqrt{\frac{\Sigma x^2 - \bar{x}\,\Sigma x}{N-1}}$$

$$S(x) = \sqrt{\frac{29.64 - (0.63)\,35.91}{49 - 1}}$$

$$S(x) = \sqrt{\frac{29.64 - 22.62}{48}} = \sqrt{\frac{7.02}{48}} = \sqrt{0.15} = 0.38$$

$$S(\bar{x}) = \frac{S(x)}{\sqrt{N}}$$

$$S(\bar{x}) = \frac{0.38}{\sqrt{49}} = \frac{0.38}{7.00} = 0.05$$

M @ 95% Confidence Level

$$M = \bar{x} \pm T0.05 \quad S(\bar{x})$$

$$M = 0.63 \pm 2.011 \quad (0.05)$$

$$M = 0.63 \pm .10 \text{ minutes}$$

MAN/MACHINE TIME CHART

Actual Charging & Blasting - Anvil Points Mine

October 1975

HOLE NO.	ELEMENT	TIME	CUMULATIVE TIME
	Get powder and set up equipment		
1	Position	2.32	2.32
	Prepare primer	-	2.32
	Install primer	-	2.32
	Load explosives	4.15	6.47
	Tie in primer	.30	6.77
2	Reposition	2.00	8.77
	Prepare primer	1.00	9.77
	Install primer	.62	10.39
	Load explosives	1.80	12.19
	Tie in primer	1.00	13.19
	DELAY: string lead wire	6.00	19.19
3	Reposition	1.48	20.67
	Prepare primer	-	20.67
	Install primer	.55	21.22
	Load explosives	2.05	23.27
	Tie in primer	.95	24.22
4	Reposition	.92	25.14
	Prepare primer	.82	25.96
	Install primer	.44	26.40
	Load explosives	1.82	28.22
	Tie in primer	-	28.22
5	Reposition	1.27	29.49
	Fill prill pot	6.16	35.65
	Prepare primer	2.45	38.10
	Install primer	.65	38.75
	Load explosives	2.11	40.86
	Tie in primer	-	40.86
6	Reposition	.75	41.61
	Prepare primer	-	41.61
	Install primer	.62	42.23
	Load explosives	1.52	43.75
	Tie in primer	-	43.75
7	Reposition	3.62	47.37
	Prepare primer	-	47.37
	Install primer	.96	48.33
	Load explosives	2.34	50.67
	Tie in primer	-	50.67

MAN/MACHINE TIME CHART

Actual Charging & Blasting - Anvil Points Mine

October 1975

HOLE NO.	ELEMENT	TIME	CUMULATIVE TIME
8	Reposition	1.09	51.76
	Prepare primer	-	51.76
	Install primer	.69	52.45
	Load explosives	2.21	54.66
	Tie in primer	-	54.66
9	Reposition	.30	54.96
	Prepare primer	-	54.96
	Install primer	.42	55.38
	Load explosives	2.22	57.60
	Tie in primer	-	57.60
10	Reposition	.32	57.92
	Prepare primer	-	57.92
	Install primer	.46	58.38
	Load explosives	1.62	60.00
	Tie in primer	-	60.00
	Fill prill pot	3.81	63.81
11	Reposition	-	63.81
	Prepare primer	-	63.81
	Install primer	.84	64.65
	Load explosives	-	64.65
	Tie in primer	-	64.65
12	Reposition	4.66	69.31
	Prepare primer	-	69.31
	Install primer	-	69.31
	Load explosives	1.69	71.00
	Tie in primer	-	71.00
13	Reposition	1.14	72.14
	Prepare primer	-	72.14
	Install primer	1.23	73.37
	Load explosives	2.52	75.89
	Tie in primer	-	75.89
	Tie in round	-	75.89
	Remove equipment	18.31	94.20
	Get powder	42.00	136.20
	Set up equipment	16.72	152.92
14	Position	1.35	154.27
	Prepare primer	1.55	155.82
	Install primer	.45	156.27
	Load explosives	1.64	157.91
	Tie in primer	1.00	158.91

MAN/MACHINE TIME CHART

Actual Charging & Blasting - Anvil Points Mine

October 1975

HOLE NO.	ELEMENT	TIME	CUMULATIVE TIME
15	Reposition	1.10	160.01
	Prepare primer	.79	160.80
	Install primer	.72	161.52
	Load explosives	2.06	163.58
	Tie in primer	.46	164.04
16	Reposition	.72	164.76
	Prepare primer	.23	164.99
	Install primer	.54	165.53
	Load explosives	2.02	167.55
	Tie in primer	.41	167.96
17	Reposition	1.01	168.97
	Prepare primer	.26	169.23
	Install primer	.36	169.59
	Load explosives	2.26	171.85
	Tie in primer	.28	172.13
	DELAY: Low air pressure	6.35	178.48
18	Reposition	1.30	179.78
	Prepare primer	-	179.78
	Install primer	.70	180.48
	Load explosives	3.02	183.50
	Tie in primer	.32	183.82
19	Reposition	.68	184.50
	Prepare primer	.50	185.00
	Install primer	.33	185.33
	Load explosives	3.52	188.85
	DELAY: no air	16.48	205.33
	Tie in primer	.26	205.59
	Fill prill pot	7.70	213.29
20	Reposition	2.00	215.29
	Prepare primer	1.50	216.79
	Install primer	.34	217.13
	Load explosives	7.26	224.39
	Tie in primer	.78	225.17
21	Reposition	-	225.17
	Prepare primer	.50	225.67
	Install primer	.51	226.18
	Load explosives	2.79	228.97
	Tie in primer	1.32	230.29

MAN/MACHINE TIME CHART

Actual Charging & Blasting - Anvil Points Mine

October 1975

HOLE NO.	ELEMENT	TIME	CUMULATIVE TIME
22	Reposition	.72	231.01
	Prepare primer	.33	231.34
	Install primer	.79	232.13
	Load explosives	2.19	234.32
	Tie in primer	.34	234.66
23	Reposition	1.09	235.75
	Prepare primer	-	235.75
	Install primer	.30	236.05
	Load explosives	2.50	238.55
	Tie in primer	.32	238.87
24	Reposition	2.31	241.18
	Prepare primer	.34	241.52
	Install primer	.55	242.07
	Fill prill pot	5.05	247.12
	Load explosives	2.30	249.42
	Tie in primer	.55	249.97
25	Reposition	1.62	251.59
	Prepare primer	.55	252.14
	Install primer	.55	252.69
	Load explosives	2.35	255.04
	Tie in primer	.42	255.46
26	Reposition	4.10	259.56
	Prepare primer	.76	260.32
	Install primer	1.53	261.85
	Load explosives	2.38	264.23
	Tie in primer	.34	264.57
27	Reposition	.80	265.37
	Prepare primer	.38	265.75
	Install primer	.65	266.40
	Load explosives	3.31	269.71
	Tie in primer	.32	270.03
28	Reposition	6.68	276.71
	Prepare primer	.39	277.10
	DELAY: blow out hole	4.95	282.05
	Install primer	.56	282.61
	Load explosives	2.18	284.79
	Tie in primer	.38	285.17

MAN/MACHINE TIME CHART

Actual Charging & Blasting - Anvil Points Mine

October 1975

HOLE NO.	ELEMENT	TIME	CUMULATIVE TIME
29	Reposition	2.70	287.87
	Prepare primer	1.00	288.87
	Install primer	1.00	289.87
	Load explosives	3.54	293.41
	Tie in primer	.39	293.80
30	Reposition	-	293.80
	Prepare primer	.52	294.32
	DELAY: blow out hole	4.00	298.32
	Install primer	.74	299.06
	Load explosives	2.53	301.59
	Tie in primer	.29	301.88
	DELAY: clean air screen	15.00	316.88
31	Reposition	3.29	320.17
	Prepare primer	.30	320.47
	DELAY: blow out hole	3.00	323.47
	Install primer	1.00	324.47
	Load explosives	2.28	326.75
	Tie in primer	.35	327.10
32	Reposition	5.08	332.18
	Prepare primer	.32	332.50
	Install primer	1.40	333.90
	Fill prill tank	5.35	339.25
	Load explosives	3.30	342.55
	Tie in primer	.41	342.96
33	Reposition	2.21	345.17
	Prepare primer	-	345.17
	Install primer	.35	345.52
	Load explosives	2.90	348.42
	Tie in primer	.39	348.81
34	Reposition	-	348.81
	Prepare primer	.49	349.30
	Install primer	.32	349.62
	Load explosive	2.44	352.06
	Tie in primer	.36	352.42

MAN/MACHINE TIME CHART

Actual Charging & Blasting - Anvil Points Mine

October 1975

HOLE NO.	ELEMENT	TIME	CUMULATIVE TIME
35	Reposition	1.94	354.36
	Prepare primer	1.20	355.56
	Install primer	.70	356.26
	Fill prill tank	5.01	361.27
	Load explosives	2.20	363.47
	Tie in primer	.39	363.86
	Tie in round	6.40	370.26
	Move out equipment	15.20	385.46
	Get powder	31.58	417.04
	Set up equipment	17.34	434.38
	Fill prill tank	6.68	441.06
36	Reposition	1.37	442.43
	Prepare primer	1.53	443.96
	Install primer	.48	444.44
	Load explosives	1.70	446.14
	Tie in primer	1.00	447.14
37	Reposition	1.11	448.25
	Prepare primer	.69	448.94
	Install primer	.75	449.69
	Load explosives	2.01	451.70
	Tie in primer	.49	452.19
38	Reposition	.70	452.89
	Prepare primer	.26	453.15
	Install primer	.58	453.73
	Load explosives	2.10	455.83
	Tie in primer	.35	456.18
39	Reposition	1.06	457.24
	Prepare primer	.23	457.47
	Install primer	.38	457.85
	Load explosives	2.30	460.15
	Tie in primer	.25	460.40
	DELAY: move truck	6.53	466.93
40	Reposition	1.33	468.26
	Prepare primer	.75	469.01
	Install primer	1.02	470.03
	Load explosives	5.06	475.09
	Tie in primer	1.20	476.29

MAN/MACHINE TIME CHART

Actual Charging & Blasting - Anvil Points Mine

October 1975

HOLE NO.	ELEMENT	TIME	CUMULATIVE TIME
41	Reposition	2.68	478.97
	Prepare primer	.34	479.31
	Install primer	.55	479.86
	Load explosives	4.05	483.91
	Tie in primer	.65	484.56
	Fill prill tank	5.10	489.66
42	Reposition	1.68	491.34
	Prepare primer	.34	491.68
	Install primer	.55	492.23
	Load explosives	2.32	494.55
	Tie in primer	.65	495.20
43	Reposition	1.32	496.52
	Prepare primer	.56	497.08
	Install primer	.53	497.61
	Load explosives	2.30	499.91
	Tie in primer	.46	500.37
44	Reposition	1.18	501.55
	Prepare primer	.67	502.22
	Install primer	1.35	503.57
	Load explosives	2.32	505.89
	Tie in primer	.31	506.20
45	Reposition	2.77	508.97
	Prepare primer	.32	509.29
	Install primer	.65	509.94
	Load explosives	3.13	513.07
	Tie in primer	.36	513.43
46	Reposition	1.78	515.21
	Prepare primer	.36	515.57
	Tie in primer	.39	519.33
47	Reposition	.65	519.98
	Prepare primer	.52	520.50
	Install primer	.38	520.88
	Load explosives	3.62	524.50
	Tie in primer	.29	524.79

MAN/MACHINE TIME CHART

Actual Charging & Blasting - Anvil Points Mine

October 1975

HOLE NO.	ELEMENT	TIME	CUMULATIVE TIME
48	Reposition	1.48	526.27
	Prepare primer	.62	526.89
	Install primer	.38	527.27
	Load explosives	4.26	531.53
	Tie in primer	.87	532.40
49	Reposition	1.63	534.03
	Prepare primer	.52	534.55
	Install primer	.50	535.05
	Load explosives	2.70	537.75
	Tie in primer	1.35	539.10
50	Reposition	.71	539.81
	Prepare primer	.36	540.17
	Install primer	.74	540.91
	Load explosives	2.10	543.01
	Tie in primer	.36	543.37
51	Reposition	1.86	545.23
	Prepare primer	.33	545.56
	Install primer	.31	545.87
	Load explosives	2.56	548.43
	Tie in primer	.38	548.81
52	Reposition	2.53	551.34
	Prepare primer	1.10	552.44
	Install primer	1.41	553.85
	Load explosives	2.97	556.82
	Tie in primer	1.08	557.90
53	Reposition	1.02	558.92
	Prepare primer	.98	559.90
	Install primer	.54	560.44
	Load explosives	3.12	563.56
	Tie in primer	1.28	564.84
	Fill prill tank	7.65	572.49
	DELAY: move truck	8.27	580.76
54	Reposition	1.08	581.84
	Prepare primer	.89	582.73
	Install primer	.87	583.70
	Load explosives	3.05	586.75
	Tie in primer	1.18	587.93

MAN/MACHINE TIME CHART

Actual Charging & Blasting - Anvil Points Mine

October 1975

HOLE NO.	ELEMENT	TIME	CUMULATIVE TIME
55	Reposition	2.85	590.78
	Prepare primer	1.05	591.83
	Install primer	1.00	592.83
	Load explosives	2.80	595.63
	Tie in primer	1.10	596.73
56	Reposition	1.60	598.33
	Prepare primer	.69	599.02
	Install primer	.76	599.78
	Load explosives	2.87	602.65
	Tie in primer	1.02	603.67
	DELAY: get one prima-det - rats chewed through wires on one	27.88	631.55
57	Reposition	1.25	632.80
	Prepare primer	.98	633.78
	Install primer	.76	634.54
	Load explosives	3.20	637.74
	Tie in primer	1.07	638.81
58	Reposition	1.00	639.81
	Prepare primer	1.02	640.83
	Install primer	.85	641.68
	Load explosives	2.88	644.56
	Tie in primer	1.18	645.74
59	Reposition	.88	646.62
	Prepare primer	.65	647.27
	Install primer	.68	647.95
	Load explosives	2.84	650.79
	Tie in primer	.55	651.34
	Tie in round	7.61	658.95
	DELAY: dead battery	21.82	680.77
	Tear down - move out	18.91	699.68

MAN/MACHINE TIME CHART

Actual Charging & Blasting - Anvil Points Mine

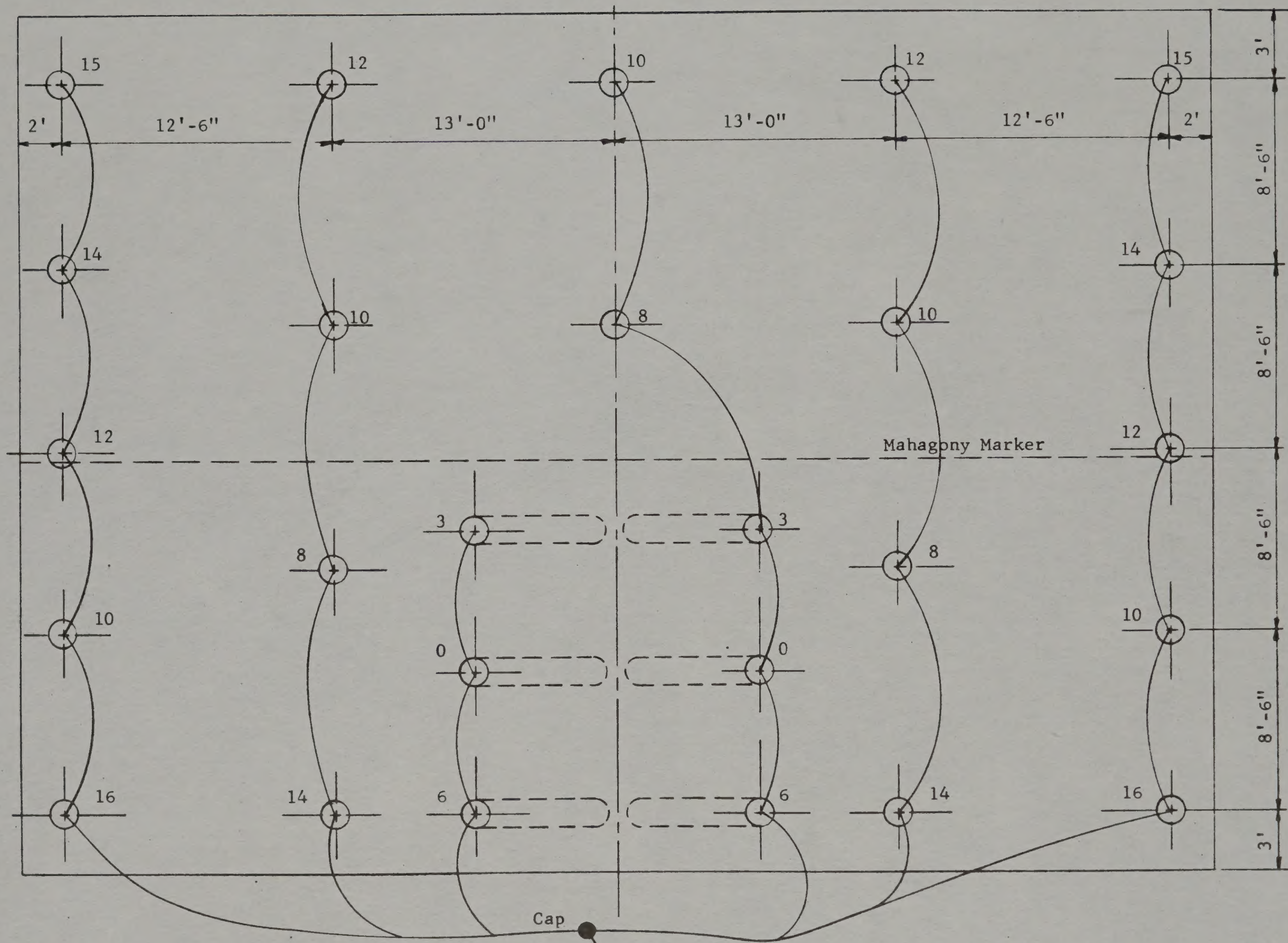
October 1975

SUMMARY SHEET

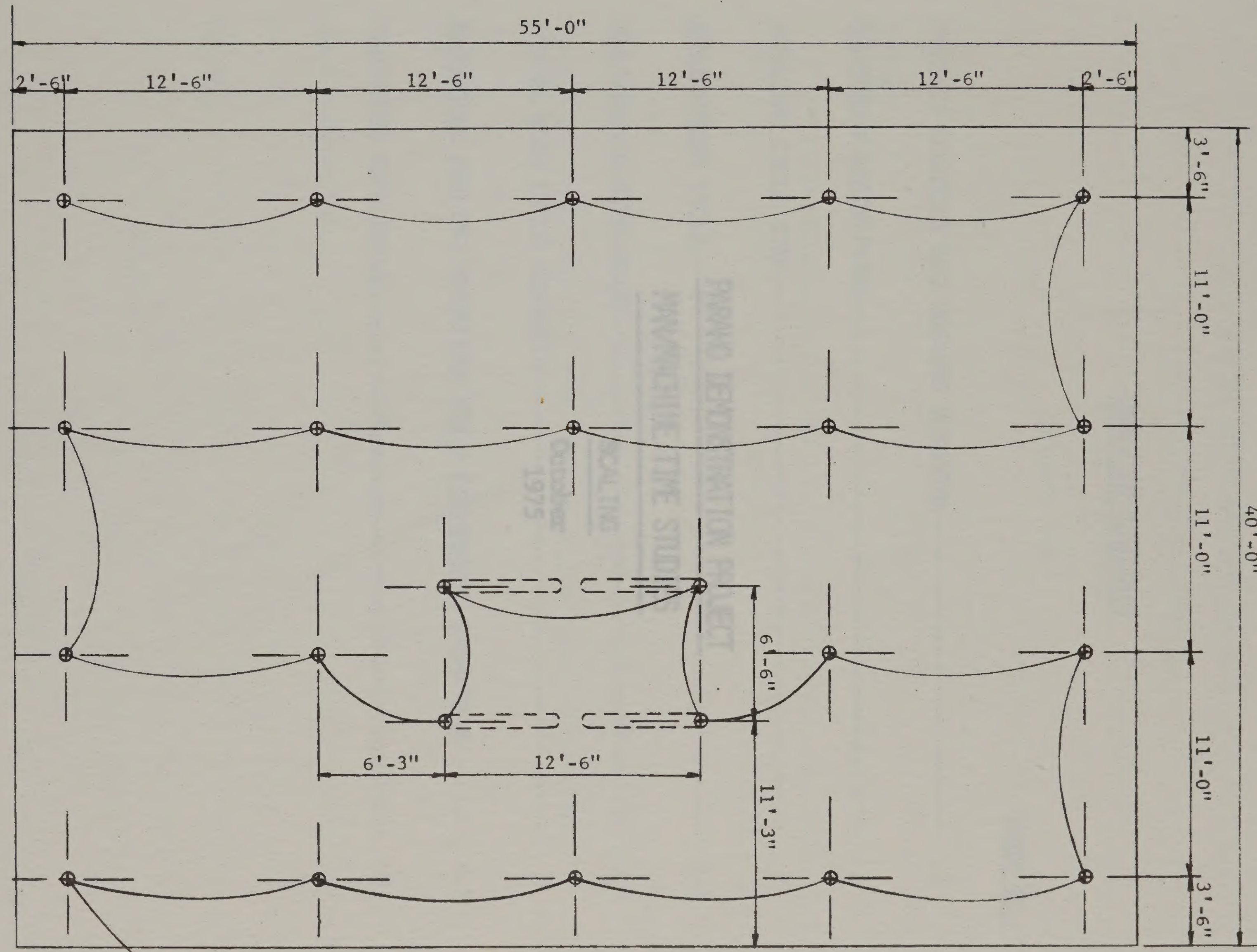
		Total Time	Occurrences of Cycle Elements	Mean	Standard Deviation	%
1.	Position	96.25	55	1.75	1.24	71%
2.	Prepare primer	31.94	46	0.6943	.44	64%
3.	Install primer	38.74	57	0.68	.32	42%
4.	Load explosives	155.04	57	2.72	.93	34%
5.	Tie in primer	30.78	49	0.63	.35	57%
6.	Fill prill pot	52.56	9	5.84	1.31	22%
7.	Move in - move out	86.48	5	17.29	1.44	8%
8.	Get powder	73.58	2	36.79	-	-
9.	Tie in round	14.01	2	7.005	-	-
10.	Delays	120.28	11			
11.	Lunches	96.55	2	48.27*	-	-
		796.23				

*Lunches include five minutes travel to lunch and five minutes return to work.

FIGURE 1



EXPLOSIVES LOADING DELAY PATTERN FOR A 26 HOLE ROUND



PROJECTED EXPLOSIVES LOADING DELAY PATTERN FOR A 23 HOLE ROUND

FIGURE 2

PARAHO DEMONSTRATION PROJECT

MAN/MACHINE TIME STUDIES

SCALING

October
1975

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PARAHO DEMONSTRATION PROJECT

MAN/MACHINE WORK STUDIES

Anvil Points Mine
Rifle, Colorado
October 1975

PROJECT:

Work Studies - Scaling

DESCRIPTION:

Work studies using elemental times were used to calculate a standard cycle time for the scaling of one twenty foot round.

PURPOSE:

Calculation of a scaling cycle time for a commercial size mining operation.

AUTHOR:

W. W. Moulton

PROJECT LOCATION AND SCALING FUNCTION

This industrial engineering project was performed at the Paraho Demonstration Project's Anvil Points Mine, near Rifle, Colorado. The mine utilizes room and pillar mining for the extraction of oil shale rock. Room dimensions are 55 feet wide and 40 feet high. A round advances twenty feet producing approximately 2,950 tons of oil shale rock. The scaling function follows the loading and hauling of this 2,950 tons of rock. Scaling of the face and ribs amounts to approximately 4,600 square feet of area in which seventy to one hundred tons of oil shale rock are produced. Some hand scaling is required in the present operation as the scaling machine will only reach to within three feet of the roof. Even with a four foot boom extension the maximum reach is thirty-seven feet.

EQUIPMENT DESCRIPTION

A Gradall 660 rubber-tired, hydraulic excavator with a telescoping boom equipped with a ripper tooth is used for scaling. The unit is diesel powered with a dry oxy-catalyst scrubber on the exhaust.

Cleanup equipment consists of a Hough 560 Pay Loader equipped with a 6.5 yard bucket and two fifty ton International Harvester Pay Hauler trucks. These are the main loading and hauling components.

STANDARD CYCLE TIME

The scaling function takes place following the loading

and hauling function. Standard cycle time is the computation of the total time required to scale the area exposed by a twenty foot round. Total time is the summation of elemental times derived from the timing of cycle elements. Cycle elements for scaling are as follows:

STANDARD CYCLE TIME:

1) Spot and respot scaler at various locations in drift
2) Scale (time duration for a given area)

The above cycle elements form a part of the total work cycle. The other parts of the total work cycle are delays and the hand scaling of the upper three feet of the face and ribs in each round. Timewise, the hand scaling element forms the major part of the total work cycle.

The man/machine time chart, page 5, is a step by step breakdown of cycle element times with a cumulative time summation. This chart is followed by a summary which shows total times, tons of rock scaled per minute, square feet scaled per minute and the number of rounds scalable per day.

ACTUAL WORK CYCLE

Scaling - 1 operator - 1 scaling machine

CONDITIONS - AREA TO BE SCALED:

Floor - Irregular

Face - 55' wide x 40' high - normal after blast

Right Rib - 30' wide x 40' high - normal after blast

Left Rib - 30' wide x 40' high - normal after blast

POSSIBLE PRODUCTIVE WORK TIME:

(Assume 100% utilization of available time)

Allowances:

Travel to Work	30 Minutes
Travel to Lunch	5 Minutes
Lunch	30 Minutes *
Return to Work Place	5 Minutes
Personal	15 Minutes
Supervision	15 Minutes
Travel from Mine	30 Minutes
	100 Minutes

* Not Paid and Not Included in Total

Total Work Day - 8 hours or 480 minutes = 480 - 100 = 380
(possible productive work time)

Actual Work Times -	Starting Time	11:20	
	Go to Lunch	12:00	40 Minutes
	Return to Work	12:45	
	Finishing Time	2:44	119 Minutes
			159 Minutes

ACTUAL WORK CYCLE

Hand Scaling Required - 4 hours - 2 men

Actual Time: 8:25 A.M. to 12:25 P.M. (Done the day after mechanical scaling was done)

ACTUAL LUNCH:

5 Minutes to Lunch

35 Minutes Lunch (30 Minutes Not Paid)

5 Minutes to Return to Work

MAN/MACHINE TIME CHART

Cycle Element	Time	Cumulative Time	Distance Traveled
Move into face	5.49	5.49	630 feet
Set up on right rib	.44	5.93	
Scaling	17.62	23.55	
Respot at right rib	.28	23.83	
Scaling	2.22	26.05	
Respot at right rib	.35	26.40	
Scaling	5.52	31.92	
Respot to left rib	.82	32.74	
Scaling	4.42	37.16	
Respot to center face	.76	37.92	
Delay: inspect face	3.92	41.84	
Delay: inspect boom	2.24	44.08	
Delay: wait for dust to clear	2.64	46.72	
Scaling	21.73	68.45	
Respot to right face	.22	68.67	
Scaling	8.20	76.87	
Respot to left rib	.98	77.85	
Scaling	17.85	95.70	
Delay: inspect boom	1.37	97.07	
Respot to left rib	.48	97.55	
Scaling	7.64	105.19	
Respot to left rib	1.04	106.23	
Scaling	8.62	114.85	
Respot to left rib	2.46	117.31	
Scaling	9.82	127.13	
Move out of face	5.32	132.45	585 feet
Clean up muck	26.55	159.00	
Lunch	45.00	204.00	
Hand scaling	240.00	444.00	

ACTUAL WORK CYCLE

SUMMARY

TOTAL TIME - MECHANICAL SCALING	159 Minutes
TOTAL TIME - HAND SCALING	240 Minutes
TOTAL TIME	399 Minutes

Mechanically scaled approximately 72 tons, 75 tons with hand scaling.

$\frac{72}{159.00}$ = .452 tons/minute scaled mechanically

$\frac{75}{399.00}$ = .188 tons/minute scaled (includes hand scaling)

$\frac{4600}{399.00}$ = 28.93 square feet/minute scaled mechanically

$\frac{\text{380 minutes/day (PPWT*)}}{159.00}$ = 2.39 rounds scaled/day mechanically

$\frac{\text{380 minutes/day (PPWT*)}}{399.00}$ = .952 rounds scaled/day (includes hand scaling)

*Possible Productive Work Time

PROJECTED SCALING REQUIREMENTS FOR A COMMERCIAL OPERATION

In order to attain maximum efficiency in the scaling function in a commercial size operation a scaling machine will have to meet the following parameters:

1. Material
   a. Oil Shale (Marlstone)
   b. 75-80 lbs./ft.
   c. Loose slabs up to 2 tons
   d. Material breaks with conchoidal fractures, has very sharp edges, is dusty, free flowing and slightly alkaline

2. Scaling Concept
   a. Upper level heading
      1) right rib 30 ft. wide X 35 ft. high
      2) face 55 ft. wide X 35 ft. high
      3) left rib 30 ft. wide X 35 ft. high
   b. Lower level bench
      1) right rib 30 ft. wide X 45 ft. high
      2) left rib 30 ft. wide X 45 ft. high
   c. One cut heading (if possible)
      1) right rib 30 ft. wide X 55 to 60 ft. high
      2) face 55 ft. wide X 55 to 60 ft. high
      3) left rib 30 ft. wide X 55 to 60 ft. high
   d. Average cycle generates 80 to 100 tons of scaled rock
   e. Scaling would be done between mucking and roof bolting- 3 shifts per day - 7 days per week
   f. Tramming distance of 300 feet between scaling areas

3. Design Factors
   a. Operator requirements
      1) one man operation from common scaling - tramming cab
      2) low operator fatigue
      3) operator safety from falling - ricocheting rock and isolation from dust
      4) operator be elevated for good visibility of full scaling height
      5) control levers have "deadman" self-centering
      6) sufficient illumination of scaling surface

      NOTE: Infrared scanners are being studied by the U. S. Bureau of Mines for detection of loose slabs to facilitate more efficient scaling.
   b. Equipment requirements
      1) scaler undercarriage maintain a safe distance from the face
      2) scaling device be a single ripper or scaling tooth with a raking or prying action
      3) anticipation of 200+ H.P. integral unit
      4) stable boom and undercarriage, to withstand severe shock from a sudden release of energy as rock comes free
      5) do effective scaling
      6) high degree of mobility
      7) acceptable equipment working availability
      8) ability to scale over the side of the carrier to cut down repositioning time
      9) productivity
      10) good availabilty of spare parts
      11) maintain low operating and maintenance cost
      12) meets Federal regulations for underground safety and emission
      13) maximum equipment life possible for low unit replacement in a 20 year or more operation

PROJECTED WORK CYCLE

A work cycle in a commercial size operation will require little or no hand scaling as the scaler will be able to reach all points in a recently blasted area. A projected work cycle time for a commercial scaling operation based on the previous scaler requirements is as follows:

1) Scale a standard size heading (approximately 4,600 square feet) in approximately 83.63 minutes

2) At 55 square feet scaled per minute

3) And based on 100 tons of scaled rock per round this equals .0217 tons of rock scaled per square foot.

ASSUME:

8 hour or 480 minute work day (collar to collar)

Allowances:

Travel to work place	10 Minutes
Lunch	30 Minutes *
Personal	15 Minutes
Supervision	10 Minutes
Return to Surface	15 Minutes
	80 Minutes

* Lunch Breakdown

5 minutes to lunch room
20 minutes to lunch
5 minutes to return to work

480 - 80 = 400 minutes (possible productive work time)

$\frac{400}{83.63}$ = 4.783 rounds scaled per 8 hour shift

= 95.66 rounds scaled per week

PARAHO DEMONSTRATION PROJECT

MAN/MACHINE WORK STUDIES

ROOF BOLTING

October
1975

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PARAHO DEMONSTRATION PROJECT

MAN/MACHINE WORK STUDIES

Anvil Points Mine
Rifle, Colorado

October 1975

PROJECT:

Work Studies - Roof Bolting

DESCRIPTION:

Work studies utilizing a break out of elemental times were used to calculate a standard cycle time for roof bolting one 20-foot round.

PURPOSE:

Calculate a roof bolting cycle for a commercial size mining operation.

AUTHOR:

W. W. Moulton

PROJECT LOCATION AND ROOF BOLT FUNCTION

This industrial engineering project was performed at the Paraho Demonstration Project's Anvil Points Mine, near Rifle, Colorado. The mine utilizes room and pillar mining for the extraction of oil shale rock. Room dimensions are 55 feet wide and 40 feet high. The roof is a natural parting plane approximately 20 feet above the Mahogany Marker.

It is felt roof bolting is necessary to create and insure a continuous and more competent roof beam.

EQUIPMENT DESCRIPTION

Roof bolting is performed by an aerial crane mounted on a rubber-tired, diesel powered carrier (Figure 1). Drilling is accomplished by a Gardner-Denver D-93 HR drill equipped with screw feed and hydraulic rotation. This drill is mounted on the crane platform.

Table I below indicates the type and manufacturer of the bits, steel, roof bolts and other accessories used in the roof bolting sequence.

TABLE I

Item	Manufacturer	Size	Remarks
Bits	Timken	1-5/8" and 1-3/4"	Tungsten/Carbide Rotary-Percussion Bit
Steel	Gardner-Denver	1-1/8" round steel with 1-1/8" Hex Shank	
Roof Bolts	Colorado Fuel & Iron	3/4" x 6', 7', & 10'	10' bolts used along ribs
Roof Bolt Anchor	Patten	D-3 Patten Expansion Shell	
Plates	Colorado Fuel & Iron	6" x 6" x 3/16"	

STANDARD CYCLE TIME

The roof bolting cycle takes place after a heading has been blasted and mucked.

Standard cycle time is the computation of the total time required to bolt the back exposed by a 20 foot round. Total time is the summation of the elemental times derived from the timing of the cycle elements. Cycle elements for roof bolting are as follows:

1. Move in, set up, tear down and move out;
2. Locate and relocate on prospective hole;
3. Collaring the hole;
4. Drilling the hole;
5. Retracting the drill;
6. Inserting the bolt;
7. Anchoring the bolt.

The above cycle elements form the major part of the total work cycle. The other part of the total work cycle is made up of various delays. These delays are noted in the man/machine charts where they occurred in the bolting sequence.

Standard industrial engineering procedures used in this analysis involve calculation of mean times, standard deviation and percent standard deviation. In order to determine if a sufficient number of element cycles were recorded to allow a confidence level of 95 percent, each element cycle was analyzed using the "t" test. This calculation is included on pages 9 to 15.

The man/machine time chart, pages 15 to 23, is a step by step breakdown of cycle element times with a cumulative time summation.

This chart is followed by a summary sheet which shows the total times, means, standard deviations and percent standard deviations for each cycle element.

ACTUAL WORK CYCLE

Roof Bolting - 1 operator - 1 drill

CONDITIONS:

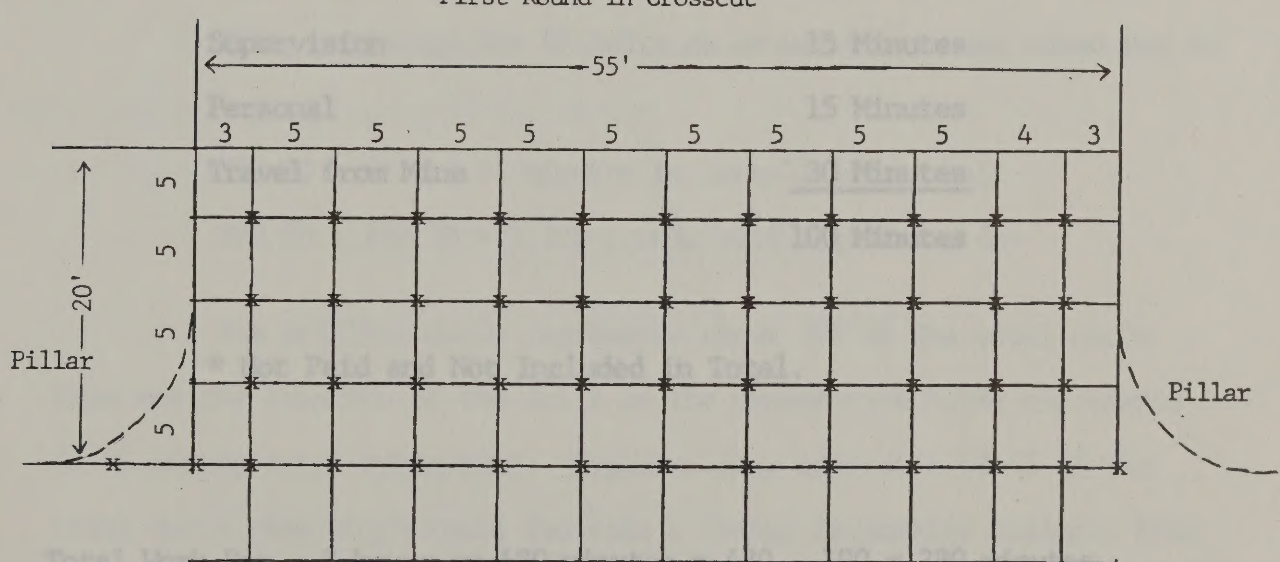
Floor - Irregular

Back - Smooth with no large fractures or irregular areas

TABLE II

ROOF BOLTING PATTERN

First Round in Crosscut



FOR THIS ROUND 47 BOLTS/ROUND WERE REQUIRED

ACTUAL WORK CYCLE

Roof Bolting - 1 operator - 1 drill

POSSIBLE PRODUCTIVE WORK TIME:

(Assume 100% utilization of available time)

Allowances:

Travel to Work	30 Minutes
Travel to Lunch	5 Minutes
Lunch	30 Minutes *
Return to Work	5 Minutes
Supervision	15 Minutes
Personal	15 Minutes
Travel from Mine	30 Minutes
	100 Minutes

* Not Paid and Not Included in Total.

Total Work Day - 8 hours or 480 minutes = 480 - 100 = 380 minutes
(possible productive work time)

Actual Work Times -	Starting Time	8:45 A.M.)	
	Go to Lunch	11:56 A.M.)	191 Minutes
	Return to Work	12:52 P.M.)	
	Finish Bolting	2:21 P.M.)	89 Minutes
			280 Minutes

ACTUAL WORK CYCLE

Roof Bolting - 1 operator - 1 drill

CYCLE ELEMENT TOTALS FOR 47 (7') BOLTS	TOTAL TIME
1. Move in, set up, tear down, move out	35.56 Minutes
2. Locate and relocate on prospective hole	70.97 Minutes*
3. Collar the hole	1.41 Minutes
4. Drill the hole	97.76 Minutes
5. Retract the drill	11.28 Minutes
6. Insert the bolt	41.36 Minutes
7. Anchor the bolt	7.52 Minutes
8. Delay time	14.00 Minutes
TOTAL	279.86 Minutes

*Time projected for 47 bolts as actual times were taken for 46

279.80 ÷ 47 = 5.95 minutes to install 1 roof bolt

380.00 ÷ 279.78 = 1.358 rounds roof bolted per day

The drilling cycle represents about 35% of the total cycle time and the location of the drill on the prospective holes represents 25.4% of the total cycle time. Together they represent 60.4% of the total cycle time which would indicate a change in machine design. This change would be an increase in the number of drills on the roof bolting jumbo. Increasing the number of drills to four would cut down on the number of times the jumbo would have to be relocated on prospective holes and would increase the number of holes drilled in conjunction with each other thus making the roof bolt function more efficient.

PROJECTED WORK CYCLE

Roof Bolting

PROJECTED ROOF BOLTING PROCEDURE FOR A COMMERCIAL OPERATION

In order to attain maximum efficiency in the roof bolting function the roof bolting jumbo will be a multiple drill; a completely mobile, self-contained unit. It will be a diesel powered, rubber-tired chassis equipped with a compressor, hydraulic pumps and storage for fuel, water, hydraulic fluid, roof bolts and roof bolt accessories. Power for the compressor and hydraulic pumps will be supplied by a diesel engine.

Table III shows a work cycle for a roof bolting jumbo equipped with four drills and operated by two men.

TABLE III - PROJECTED WORK CYCLE

Roof Bolting - 2 operators - 4 drills

$$\frac{\text{Total time to roof bolt 1 round, 1 operator - 1 drill (minus delays and move in and move out time)}}{\text{Factor for 2 operators - 4 drills}} = \frac{230.30}{3.8} = 60.60$$

	60.60
Move in - move out	35.56
Add delays	14.00
Total Time	110.16

ASSUME

8 hour or 480 minute work day (collar to collar)

ALLOWANCES

Travel to work place	10.00 Minutes
Lunch	30.00 Minutes *
Personal	15.00 Minutes
Supervision	10.00 Minutes
Return to surface	15.00 Minutes
	80.00 Minutes

*Assume 5 minutes travel to lunch; 20 minutes lunch and 5 minutes return to work.

480 - 80 = 400 (possible productive work time)

400 ÷ 110.16 = 3.631 rounds roof bolted per 8 hour shift, or approximately 72.621 rounds per week, based on 20 shifts per week.

ROOF BOLTING - LOCATION AND RELOCATION TIME IN MINUTES

Calculations to estimate true mean (M) from sample data.

$\Sigma x = 69.46$

$N = 46$

$\bar{x} = 1.51$

$\Sigma x^2 = 109.02$

$$S(x) = \sqrt{\frac{\Sigma x^2 - \bar{x}\Sigma x}{N-1}}$$

$$S(x) = \sqrt{\frac{109.02 - 1.51(69.46)}{46-1}}$$

$$S(x) = \sqrt{\frac{109.02 - 104.88}{45}} = \sqrt{\frac{4.14}{45}} \quad \sqrt{0.09} = 0.30$$

$$S(\bar{x}) = \frac{S(x)}{\sqrt{N}}$$

$$S(\bar{x}) = \frac{0.30}{\sqrt{46}} = \frac{0.30}{6.78} = 0.04$$

M @ 95% Confidence Level

$M = \bar{x} \pm T\ 0.05\ S(\bar{x})$

$M = 1.51 \pm 2.014\ (.04)$

$M = 1.51 \pm 0.09$ minutes

ROOF BOLTING - COLLARING THE HOLE

Calculation to estimate true mean (M) from sample data.

$\Sigma x \; = \; 1.41$

$N \; = \; 47$

$\bar{x} \; = \; 0.03$

$\Sigma x^2 \; = \; 0.0492$

$$S(x) = \sqrt{\frac{\Sigma x^2 - \bar{x}\,\Sigma x}{N-1}}$$

$$S(x) = \sqrt{\frac{0.0492 - 0.03(1.41)}{47-1}}$$

$$S(x) = \sqrt{\frac{0.0492 - 0.0423}{46}} = \sqrt{\frac{0.0069}{46}} = \sqrt{0.0002} \qquad 0.122$$

$$S(\bar{x}) = \frac{S(x)}{\sqrt{N}}$$

$$S(\bar{x}) = \frac{0.0122}{\sqrt{47}} = \frac{0.0122}{6.8557} = .0018$$

M @ 95% Confidence Level

$M = \bar{x} \pm T\ 0.05\ S(\bar{x})$

$M = 0.03 \pm 2.0133\ (.0018)$

$M = 0.03 \pm 0.0036$ minutes

ROOF BOLTING - DRILLING THE HOLE

Calculations to estimate true mean (M) from sample data.

$$\Sigma x = 97.76$$

$$N = 47$$

$$\bar{x} = 2.08$$

$$\Sigma x^2 = 206.84$$

$$S(x) = \sqrt{\frac{\Sigma x^2 - \bar{x}\ \Sigma x}{N-1}}$$

$$S(x) = \sqrt{\frac{206.84 - (2.08)\ (97.76)}{47-1}}$$

$$S(x) = \sqrt{\frac{206.84 - 203.34}{46}} = \sqrt{\frac{3.50}{46}} \quad \sqrt{0.08} \quad 0.28$$

$$S(\bar{x}) = \frac{S(x)}{\sqrt{N}}$$

$$S(\bar{x}) = \frac{0.28}{\sqrt{47}} = \frac{0.28}{6.68} = 0.04$$

M @ 95% Confidence Level

$M = \bar{x} \pm T\ 0.05 \quad S(\bar{x})$

$M = 2.08 \pm 2.013\ (0.04)$

$M = 2.08 \pm 0.08$ minutes

Calculations to estimate true mean (M) from sample data.

$\Sigma x = 11.28$

$N = 47$

$\overline{x} = 0.24$

$\Sigma x^2 = 2.68$

$$S(x) = \sqrt{\frac{\Sigma x^2 - \overline{x}\ \Sigma(x)}{N-1}}$$

$$S(x) = \sqrt{\frac{2.68 - 0.24(11.28)}{47-1}}$$

$$S(x) = \sqrt{\frac{2.68 - 2.70}{46}} = \sqrt{\frac{-.02}{46}} = \sqrt{.00043} = .0208$$

$$S(\overline{x}) = \frac{S(x)}{\sqrt{N}}$$

$$S(\overline{x}) = \frac{.0208}{\sqrt{47}} = \frac{.0208}{6.85} = 0.003$$

M @ 95% Confidence Level

$M = \overline{x} \pm T\ 0.05\ \ S(\overline{x})$

$M = 0.24 \pm 2.013\ (0.003)$

$M = 0.24 \pm 0.006$ minutes

ROOF BOLTING - INSERT ROOF BOLT

Calculations to estimate true mean (M) from sample data.

$\Sigma x = 41.36$

$N = 47$

$\bar{x} = 0.88$

$\Sigma x^2 = 36.19$

$$S(x) = \sqrt{\frac{\Sigma x^2 - \bar{x}\,\Sigma x}{N-1}}$$

$$S(x) = \sqrt{\frac{36.19 - .88(41.36)}{47-1}}$$

$$S(x) = \sqrt{\frac{36.19 - 36.40}{46}} = \sqrt{\frac{-.21}{46}} = \sqrt{.0046} = 0.0676$$

$$S(\bar{x}) = \frac{S(x)}{\sqrt{N}}$$

$$S(\bar{x}) = \frac{.0676}{\sqrt{47}} = \frac{.0676}{6.85} = .0099$$

M @ 95% Confidence Level

$M = \bar{x} \pm T\ 0.05\ S(\bar{x})$

$M = 0.88 \pm 2.93\ (.0099)$

$M = 0.88 \pm 0.0199$ minutes

ROOF BOLTING - ANCHOR BOLT

Calculations to estimate true mean (M) from sample data.

$\Sigma x = 7.52$

$N = 47$

$\bar{x} = .16$

$\Sigma x^2 = 1.37$

$$S(x) = \sqrt{\frac{\Sigma x^2 - \bar{x}\ \Sigma x}{N-1}}$$

$$S(x) = \sqrt{\frac{1.37 - (.16)\ (7.52)}{47-1}}$$

$$S(x) = \sqrt{\frac{1.37 - 1.20}{46}} = \sqrt{\frac{.17}{46}} \quad \sqrt{.0036} = .06079$$

$$S(\bar{x}) = \frac{S(x)}{\sqrt{N}}$$

$$S(\bar{x}) = \frac{.06}{\sqrt{47}} = \frac{.06079}{6.85} = .0088$$

M @ 95% Confidence Level

$M = \bar{x} \pm T\ 0.05\ S(\bar{x})$

$M = .16 \pm 2.013\ (.0088)$

$M = .16 \pm\ .017$ minutes

MAN/MACHINE TIME CHART

Actual Roof Bolting - Anvil Points Mine

October 1975

HOLE NO.	ELEMENT	TIME	CUMULATIVE TIME
1	Move into face	2.40	2.40
	Set up to bolt	24.00	26.40
	Collar hole	.05	26.45
	Drill hole	2.36	28.81
	Retract drill	.23	29.04
	Insert bolt	1.24	30.28
	Anchor bolt	.13	30.41
2	Relocate	1.42	31.83
	Collar hole	.08	31.91
	Drill hole	2.42	34.33
	Retract drill	.22	34.55
	Insert bolt	.91	35.46
	Anchor bolt	.13	35.59
3	Relocate	2.00	37.59
	Collar hole	.04	37.63
	Drill hole	2.09	39.72
	Retract drill	.21	39.93
	Insert bolt	.85	40.78
	Anchor bolt	.12	40.90
4	Relocate	1.11	42.01
	Collar hole	.03	42.04
	Drill hole	2.11	44.15
	Retract drill	.22	44.37
	Insert bolt	.88	45.25
	Anchor bolt	.13	45.38
5	Relocate	2.00	47.38
	Collar hole	.04	47.42
	Drill hole	2.02	49.44
	Retract drill	.24	49.68
	Insert bolt	.88	50.56
	Anchor bolt	.19	50.75
6	Relocate	1.48	52.23
	Collar hole	.03	52.26
	Drill hole	2.58	54.84
	Retract drill	.23	55.07
	Insert bolt	.87	55.94
	Anchor bolt	.13	56.07

MAN/MACHINE TIME CHART

Actual Roof Bolting - Anvil Points Mine

October 1975

HOLE NO.	ELEMENT	TIME	CUMULATIVE TIME
7	Relocate	1.54	57.61
	Collar hole	.04	57.65
	Drill hole	2.22	59.87
	Retract drill	.20	60.07
	Insert bolt	.91	60.98
	Anchor bolt	.15	61.13
8	Relocate	1.58	62.71
	Collar hole	.02	62.73
	Drill hole	2.13	64.86
	Retract drill	.23	65.09
	Insert bolt	.85	65.94
	Anchor bolt	.18	66.12
9	Relocate	2.14	68.26
	Collar hole	.03	68.29
	Drill hole	2.93	71.22
	Retract drill	.24	71.46
	Insert bolt	.89	72.35
	Anchor bolt	.12	72.47
10	Relocate	1.20	73.67
	Collar hole	.03	73.70
	Drill hole	2.21	75.91
	Retract drill	.24	76.15
	Insert bolt	.86	77.01
	Anchor bolt	.09	77.10
11	Relocate	1.62	78.72
	Collar hole	.03	78.75
	Drill hole	2.17	80.92
	Retract drill	.23	81.15
	Insert bolt	.83	81.98
	Anchor bolt	.09	82.07
12	Relocate	1.88	83.95
	Collar hole	.03	83.98
	Drill hole	2.28	86.26
	Retract drill	.24	86.50
	Insert bolt	1.26	87.76
	Anchor bolt	.14	87.90

MAN/MACHINE TIME CHART

Actual Roof Bolting - Anvil Points Mine

October 1975

HOLE NO.	ELEMENT	TIME	CUMULATIVE TIME
13	Relocate	1.11	89.01
	Collar hole	.03	89.04
	Drill hole	1.98	91.02
	Retract drill	.22	91.24
	Insert bolt	.78	92.02
	Anchor bolt	.13	92.15
14	Relocate	1.35	93.50
	Collar hole	.04	93.54
	Drill hole	2.06	95.60
	Retract drill	.23	95.83
	Insert bolt	.86	96.69
	Anchor bolt	.18	96.87
15	Relocate	1.42	98.29
	Collar hole	.03	98.32
	Drill hole	2.12	100.44
	Retract drill	.23	100.67
	Insert bolt	.81	101.48
	Anchor bolt	.13	101.61
16	Relocate	1.89	103.50
	Collar hole	.04	103.54
	Drill hole	2.22	105.76
	Retract drill	.29	106.05
	Insert bolt	.77	106.82
	Anchor bolt	.15	106.97
17	Relocate	1.39	108.36
	Collar hole	.03	108.39
	Drill hole	1.98	110.37
	Retract drill	.22	110.59
	Insert bolt	.84	111.43
	Anchor bolt	.16	111.59
18	Relocate	1.46	113.05
	Collar hole	.02	113.07
	Drill hole	2.02	115.09
	Retract drill	.25	115.34
	Insert bolt	.83	116.17
	Anchor bolt	.16	116.33

MAN/MACHINE TIME CHART

Actual Roof Bolting - Anvil Points Mine

October 1975

HOLE NO.	ELEMENT	TIME	CUMULATIVE TIME
19	Relocate	1.21	117.54
	Collar hole	.02	117.56
	Drill hole	1.96	119.52
	Retract drill	.21	119.73
	Insert bolt	.82	120.55
	Anchor bolt	.12	120.67
20	Relocate	2.09	122.76
	Collar hole	.03	122.79
	Drill hole	2.01	124.80
	Retract drill	.24	125.04
	Insert bolt	.88	125.92
	Anchor bolt	.18	126.10
21	Relocate	1.36	127.46
	Collar hole	.03	127.49
	Drill hole	2.04	129.53
	Retract drill	.24	129.77
	Insert bolt	.82	130.59
	Anchor bolt	.21	130.80
22	Relocate	1.36	132.16
	Collar hole	.03	132.19
	Drill hole	2.02	134.21
	Retract drill	.23	134.44
	Insert bolt	.88	135.32
	Anchor bolt	.18	135.50
23	Relocate	1.35	136.85
	Collar hole	.02	136.87
	Drill hole	2.26	139.13
	Retract drill	.23	139.36
	Insert bolt	.84	140.20
	Anchor bolt	.12	140.32
	DELAY - get more bolts and plates	9.00	149.32
24	Relocate	1.51	150.83
	Collar hole	.03	150.86
	Drill hole	2.18	153.04
	Retract drill	.24	153.28
	Insert bolt	.83	154.11
	Anchor bolt	.23	154.34

MAN/MACHINE TIME CHART

Actual Roof Bolting - Anvil Points Mine

October 1975

HOLE NO.	ELEMENT	TIME	CUMULATIVE TIME
25	Relocate	1.38	155.72
	Collar hole	.04	155.76
	Drill hole	1.97	157.73
	Retract drill	.24	157.97
	Insert bolt	.90	158.87
	Anchor bolt	.13	159.00
26	Relocate	1.19	160.19
	Collar hole	.03	160.22
	Drill hole	2.57	162.79
	Retract drill	.25	163.04
	Insert bolt	.87	163.91
	Anchor bolt	.12	164.03
27	Relocate	1.69	165.72
	Collar hole	.03	165.75
	Drill hole	2.02	167.77
	Retract drill	.29	168.06
	Insert bolt	.91	168.97
	Anchor bolt	.20	169.17
28	Relocate	1.41	170.58
	Collar hole	.04	170.62
	Drill hole	2.09	172.71
	Retract drill	.21	172.92
	Insert bolt	.89	173.81
	Anchor bolt	.12	173.93
29	Relocate	1.19	175.12
	Collar hole	.02	175.14
	Drill hole	2.03	177.17
	Retract drill	.23	177.40
	Insert bolt	.86	178.26
	Anchor bolt	.16	178.42
30	Relocate	1.51	179.93
	Collar hole	.03	179.96
	Drill hole	2.45	182.41
	Retract drill	.25	182.66
	Insert bolt	.94	183.60
	Anchor bolt	.21	183.81

MAN/MACHINE TIME CHART

Actual Roof Bolting - Anvil Points Mine

October 1975

HOLE NO.	ELEMENT	TIME	CUMULATIVE TIME
31	Relocate	1.74	185.55
	Collar hole	.02	185.57
	Drill hole	2.49	188.06
	Retract drill	.22	188.28
	Insert bolt	.94	189.22
	Anchor bolt	.13	189.35
32	Relocate	1.23	190.58
	Collar hole	.03	190.61
	Drill hole	1.91	192.52
	Retract drill	.26	192.78
	Insert bolt	.87	193.65
	Anchor bolt	.26	193.91
33	Relocate	1.26	195.17
	Collar hole	.03	195.20
	Drill hole	2.08	197.28
	Retract drill	.26	197.54
	Insert bolt	.99	198.53
	Anchor bolt	.14	198.67
34	Relocate	1.86	200.53
	Collar hole	.02	200.55
	Drill hole	1.86	202.41
	Retract drill	.22	202.63
	Insert bolt	1.19	203.82
	Anchor bolt	.16	203.98
35	Relocate	1.31	205.29
	Collar hole	.04	205.33
	Drill hole	1.12	206.45
	Retract drill	.28	206.73
	Insert bolt	.86	207.59
	Anchor bolt	.18	207.77
36	Relocate	1.42	209.19
	Collar hole	.03	209.22
	Drill hole	2.08	211.30
	Retract drill	.26	211.56
	Insert bolt	.85	212.41
	Anchor bolt	.15	212.56

MAN/MACHINE TIME CHART

Actual Roof Bolting - Anvil Points Mine

October 1975

HOLE NO.	ELEMENT	TIME	CUMULATIVE TIME
37	Relocate	1.15	213.71
	Collar hole	.02	213.73
	Drill hole	1.88	215.61
	Retract drill	.24	215.85
	Insert bolt	.81	216.66
	Anchor bolt	.15	216.81
38	Relocate	1.06	217.87
	Collar hole	.03	217.90
	Drill hole	2.07	219.97
	Retract drill	.25	220.22
	Insert bolt	.83	221.05
	Anchor bolt	.19	221.24
39	Relocate	1.77	223.01
	Collar hole	.02	223.03
	Drill hole	1.95	224.98
	Retract drill	.22	225.20
	Insert bolt	.89	226.09
	Anchor bolt	.33	226.42
40	Relocate	1.21	227.63
	Collar hole	.03	227.66
	Drill hole	1.76	229.42
	Retract drill	.23	229.65
	Insert bolt	.79	230.44
	Anchor bolt	.16	230.60
41	Relocate	1.13	231.73
	Collar hole	.02	231.75
	Drill hole	1.89	233.64
	Retract drill	.26	233.90
	Insert bolt	.82	234.72
	Anchor bolt	.17	234.89
42	Relocate	1.82	236.71
	Collar hole	.03	236.74
	Drill hole	1.86	238.60
	Retract drill	.24	238.84
	Insert bolt	.80	239.64
	Anchor bolt	.22	239.86

MAN/MACHINE TIME CHART

Actual Roof Bolting - Anvil Points Mine

October 1975

HOLE NO.	ELEMENT	TIME	CUMULATIVE TIME
43	Relocate	1.70	241.56
	Collar hole	.03	241.59
	Drill hole	1.79	243.38
	Retract drill	.26	243.64
	Insert bolt	.81	244.45
	Anchor bolt	.16	244.61
44	Relocate	1.64	246.25
	Collar hole	.04	246.29
	Drill hole	1.86	248.15
	Retract drill	.25	248.40
	Insert bolt	.78	249.18
	Anchor bolt	.18	249.36
45	Relocate	1.72	251.08
	Collar hole	.02	251.10
	Drill hole	1.86	252.96
	Retract drill	.25	253.21
	Insert bolt	.88	254.09
	Anchor bolt	.15	254.24
46	Relocate	2.32	256.56
	Collar hole	.02	256.58
	Drill hole	1.88	258.46
	Retract drill	.23	258.69
	Insert bolt	.94	259.63
	Anchor bolt	.17	259.80
	DELAY - get one bolt	5.00	264.80
47	Relocate	1.26	266.06
	Collar hole	.02	266.08
	Drill hole	1.96	268.04
	Retract drill	.27	268.31
	Insert bolt	.86	269.17
	Anchor bolt	.18	269.35
	Tear down, move out	9.00	278.35

MAN/MACHINE TIME CHART

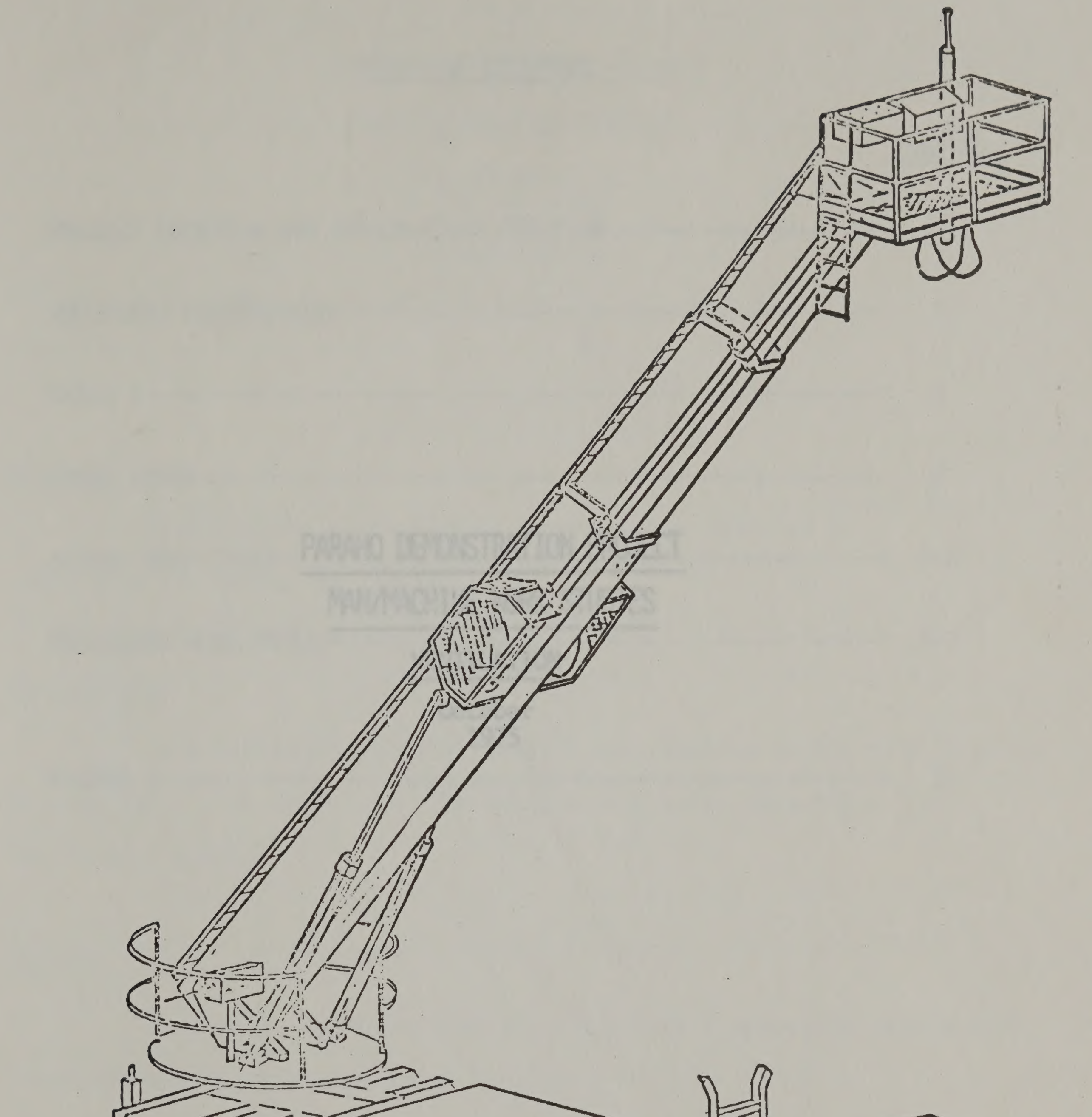
Actual Roof Bolting - Anvil Points Mine

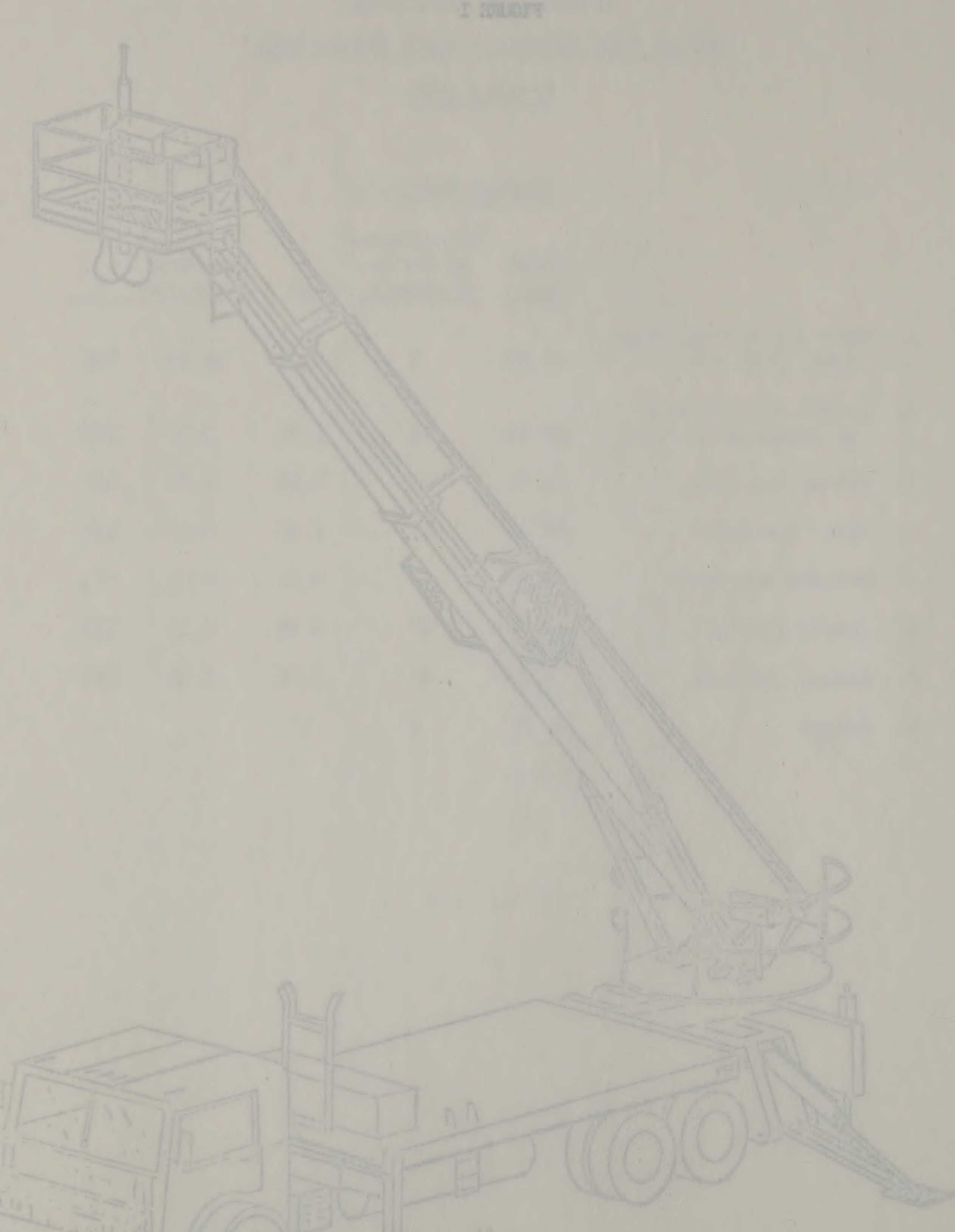
October 1975

SUMMARY SHEET

	Total Time	Occurrences of Cycle Elements	Mean	Standard Deviation	%
1. Move in, set up, tear down, move out	35.56	2	17.78	12.30	70%
2. Locate and relocate on prospective hole	69.46	46	1.51	0.30	20%
3. Collar the hole	1.41	47	0.03	0.01	35%
4. Drill the hole	97.76	47	2.08	0.27	13%
5. Retract the drill	11.28	47	0.24	0.02	8%
6. Insert the bolt	41.36	47	0.88	0.10	12%
7. Anchor the bolt	7.52	47	0.16	0.04	29%
8. Delays	14.00	2	-	-	-
	278.35				

FIGURE I





PARAHO DEMONSTRATION PROJECT

MAN/MACHINE WORK STUDIES

VENTILATION

October
1975

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PARAHO DEMONSTRATION PROJECT

MAN/MACHINE WORK STUDIES

Anvil Points Mine
Rifle, Colorado

October 1975

PROJECT:

Work Studies - Ventilation System - time required in expanding and moving the system.

DESCRIPTION:

Data collection on this function was directed to the time involved to take down, move and install the various components comprising the ventilation system.

PURPOSE:

To develop standard times for a commercial operation from actual times observed in the pilot mine.

AUTHOR:

W. W. Moulton

PROJECT LOCATION AND VENTILATION FUNCTION

This industrial engineering project was performed at the Paraho Demonstration Project's Anvil Points Mine, near Rifle, Colorado. The mine utilizes room and pillar mining for the extraction of oil shale rock. With room dimensions of 55 feet wide and 40 feet high, an efficient ventilation system is needed.

EQUIPMENT DESCRIPTION

Ventilation in the Anvil Points Mine is accomplished by the use of fans, both permanently placed and mobile. The permanently placed fan is six feet in diameter and is installed approximately 800 feet from the Able Drift portal entrance (see diagram, page 8). The other two fans are mobile and are moved into working areas.

Table I indicates the size, horsepower of the motor, manufacturer and cubic feet of air moved per minute for each fan.

Equipment used in the process of moving the 72" fan included the roof bolting carrier, powder monkey carrier and the Hough 560 Pay Loader.

TABLE I

DIAMETER	MOTOR H.P.	MANUFACTURER & RPM		CUBIC FEET OF AIR MOVED/MINUTE
72"	75 H.P.	Joy	4,400	100,000
32"	40 H.P.	Joy	3,450	Not Available
28"	15 H.P.	Joy	1,725	Not Available

CYCLE TIMES

Cycle times were taken when the six foot Joy fan was moved 150 feet further into Able Drift. Cycle times were taken for the following elements:

1. Unhook electricals and take down the fan;
2. Install roof bolts to hang the fan;
3. Hang the fan 150 feet from previous location;
4. String electrical cable to the fan;
5. Hang vent bag to the fan;
6. Hook up fan electricals.

ACTUAL WORK CYCLE

Ventilation System - 6 Men

CONDITIONS:

Floor - Smooth and Clean

Back - Smooth with Roof Bolts

POSSIBLE PRODUCTIVE WORK TIME:

(Assume 100% utilization of available time)

Allowances:

Travel to Mine	30 Minutes
Travel to Lunch	5 Minutes
Lunch	30 Minutes *
Return to Work	5 Minutes
Supervision	15 Minutes
Personal	15 Minutes
Travel from Mine	30 Minutes
	100 Minutes

* Not Paid and Not Included in Total.

Total Work Day - 8 hours or 480 minutes = 480 - 100 = 380 minutes (possible productive work time)

Actual Work Times -	August 14, 1975	August 15, 1975
Starting Time	10:38 A.M.	8:10 A.M.
Finishing Time	6:02 P.M.	6:00 P.M.
Total Minutes Working Time	444 Minutes	590 Minutes

ACTUAL WORK CYCLE

August 14, 1975 - Five men worked a total of 729.22 man-minutes or 12.15 man-hours.

	Two Men
Unhook electricals and take down fan	63.55 Minutes
Tie Ventilation Bag Together (6 sections)	192.06 Minutes

	One Man
Install roof bolts to hang fan and vent bag	143.00 Minutes

Lunch: 5.0 Minutes to Lunch
35.0 Lunch (30 Minutes not paid)
5.0 Minutes return to work

Total: 45.0 Minutes

443.61 Minutes

Minus (30 minute not paid lunch) 30.00 Minutes

413.61 Total Working Minutes

August 15, 1975 - Seven men worked a total of 2,223 man-minutes or 37.05 man-hours.

	Three Men
Hang Fan	230.00 Minutes
	Two Men
String up Electrical Cable	79.00 Minutes
	Three Men
Hang Vent Bag	240.00 Minutes
	Two Men
Hook up Electricals	240.00 Minutes

Lunch: 5.0 Minutes to Lunch
45.0 Minutes Lunch (30 minutes not paid)
5.0 Minutes Return to Work

Total: 55.0 Minutes

844.00 Minutes

Minus (30 minute lunch) 30.00 Minutes

Total Working Minutes 814.00

Total man-hours required to take down, move and install various components comprising the ventilation system are as follows:

August 14, 1975: 729.22 man-minutes = 12.15 man-hours

August 15, 1975: 2223.00 man-minutes = 37.05 man-hours

Total Man-Hours 49.20

System was moved 150 feet - $\frac{150 \text{ feet}}{49.20}$ = 3.05 feet per man-hour

BREAK OUT THREE ELEMENTS

These elements are: tie the vent bag together, roof bolt to hang vent bag and hang vent bag are as follows: (times are in man-minutes)

Tie vent bag together (6 sections)	384.12 Man-Minutes
Roof bolt to hang vent bag	143.00 Man-Minutes
Hang vent bag	720.00 Man-Minutes
	1246.12 Man-Minutes

$\frac{1247.12}{60}$ = 20.78 Man-Hours

$\frac{150 \text{ ft.}}{20.78}$ = 7.21 feet/man-hour to assemble vent bag sections, roof bolt to hang vent bag and hang vent bag.

PROJECTED WORK CYCLE

COMMERCIAL OPERATION

In projecting a work cycle for the moving of certain components of a ventilation system some important factors will have to be considered. A commercial size operation will require a trained crew with special equipment to keep the progress of the ventilation system in conjunction with mine development. In view of the immense size of an oil shale mine, the large tonnages of rock that will be handled and the vast amounts of

dust that will exist it is suggested that an excess in the minimum air requirements be relied upon to provide adequately clean air at the work face. Also the choice of certain mine designs and sequences in operations will aid in the development of an adequate ventilation system.

Colorado State mining laws require an underground operation using diesel powered equipment to supply 100 cubic feet of air per minute for each diesel horsepower operating in the mine. In addition to the above requirement, an additional 75 cubic feet of air per minute must be supplied for every man working in the mine.

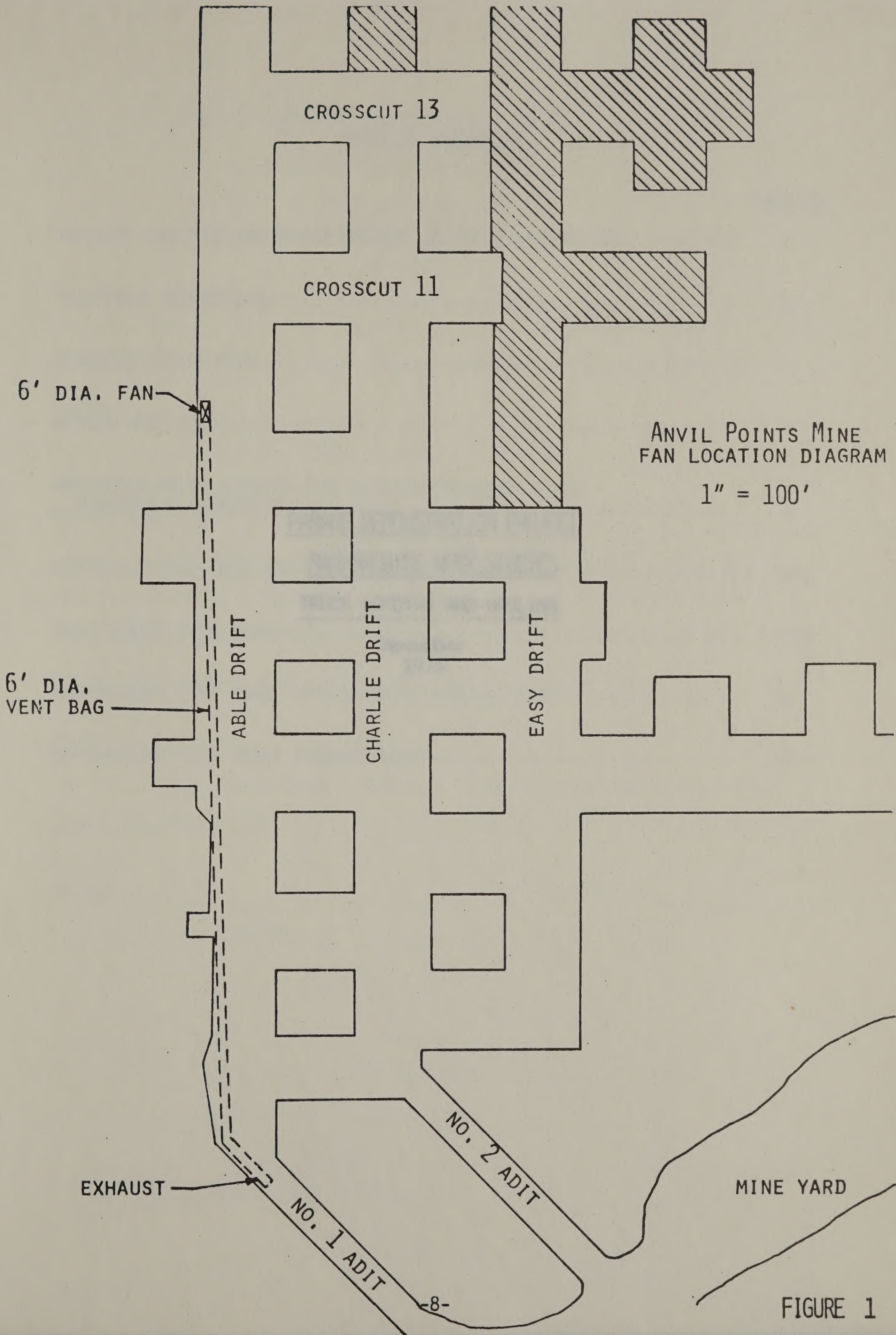
CROSSCUT 13
CROSSCUT 11
6' DIA. FAN
ANVIL POINTS MINE
FAN LOCATION DIAGRAM
1" = 100'
6' DIA.
VENT BAG
ABLE DRIFT
CHARLIE DRIFT
EASY DRIFT
NO. 2 ADIT
EXHAUST
MINE YARD
NO. 1 ADIT

FIGURE 1

PARAHO DEMONSTRATION PROJECT

MAN/MACHINE WORK STUDIES

TRUCK LOADING AND HAULING

November
1975

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PARAHO DEMONSTRATION PROJECT

MAN/MACHINE WORK STUDIES

Anvil Points Mine
Rifle, Colorado

November 1975

PROJECT:

Work Studies - Truck Loading and Hauling

DESCRIPTION:

Work studies utilizing a break out of elemental times were used to calculate a standard cycle time for truck loading and hauling rock produced from one twenty foot round. The standard twenty foot round produces approximately 2,950 tons of oil shale rock.

PURPOSE:

Calculate a truck loading and hauling cycle for a commercial size mining operation.

AUTHOR:

W. W. Moulton

PROJECT LOCATION AND TRUCK LOADING AND HAULING FUNCTION

This industrial engineering project was performed at the Paraho Demonstration Project's Anvil Points Mine near Rifle, Colorado. The mine utilizes room and pillar mining for the extraction of oil shale rock. Room dimensions are 55 feet wide by 40 feet high. Each round is designed to advance 20 feet and produce approximately 2,950 tons of oil shale rock.

EQUIPMENT DESCRIPTION

Truck loading is performed by a Hough 560 Payloader equipped with a 6.5 cubic yard bucket. Trucks are 50 ton International Payhaulers.

STANDARD CYCLE TIME

The truck loading and hauling function takes place after the charging and blasting function.

Standard cycle time is the computation of the total time required to load and haul a truckload of oil shale rock. Total time is the summation of elemental times derived from the timing of cycle elements. Cycle elements for the truck loading function are as follows:

1. Doze the muck pile.
2. Load the bucket.
3. Back and turn towards truck.
4. Travel loaded towards truck.
5. Dump into truck.
6. Travel empty to muck pile.

The truck hauling function cycle time is the total time it takes a truck to make a round trip from the mine to the crusher stockpile. This time includes the loading function time and is listed on page 18. The mean, standard deviation and percent standard deviation are also on this page.

Standard industrial engineering procedures used in the truck loading and hauling analysis involved calculation of mean times, standard deviation and percent standard deviation.

In order to determine if a sufficient number of element cycles were recorded to allow a confidence level of 95% each element cycle was analyzed using the "t" test. This calculation is included on pages 6 to 11. The "t" test for truck hauling is on page 6.

The man/machine time chart, pages 12 to 18, is a step by step breakdown of cycle element times with a cumulative time summation. This chart is followed by a summary sheet, page 20 which shows the total time, mean, standard deviation and percent standard deviation for each cycle element.

ACTUAL WORK CYCLE

Truck Loading and Hauling

1. Loader (equipped with a 6.5 cubic yard bucket)
2. Trucks (50 ton rating)

CONDITIONS:

Roads - in face (muck pile) area - irregular

- haulage roads in mine - good (smooth)
- haulage roads from mine portal to crusher - smooth with excessive grade

POSSIBLE PRODUCTIVE WORK TIME:

(Assume 100% utilization of available time)

Allowances:

Travel to Work	30 Minutes
Travel to Lunch	5 Minutes
Lunch	30 Minutes *
Return to Work	5 Minutes
Supervision	15 Minutes
Personal	15 Minutes
Travel from Mine	30 Minutes
	100 Minutes

* Not Paid and Not Included in Total.

Total Work Day - 8 hours or 480 minutes = 480 - 100 = 380 minutes
(possible productive work time)

CYCLE ELEMENT (TOTALS) FOR TRUCK LOADING:

These numbers are based on the timing of actual cycle elements; these times are for the loading of one bucket.

1. Doze the muck pile	.09 Minutes
2. Load bucket	.12 Minutes
3. Back and turn	.16 Minutes
4. Travel loaded	.17 Minutes
5. Dump into truck	.09 Minutes
6. Travel empty	.09 Minutes
	0.72 Minutes

Truck Hauling

With a haulage road distance of 5.5 miles from the mine to the crusher stockpile it takes a truck 62.625 minutes to complete a round trip (including loading the truck)

Based on a 1.05 ton/cubic yard - approximately nine loader buckets are required to fill a truck. This equals 6.48 minutes.

$$\begin{array}{rl} 62.625 & \text{Minutes (truck round trip)} \\ -\ \ \underline{6.48} & \text{Minutes (truck loading)} \\ 56.145 & \text{Minutes (truck hauling time)} \end{array}$$

5.5 miles = 29,040 feet=29.04 thousand feet $\frac{56.145}{29.04}$ = 1.93 min./1000 feet

1.93 min x 5.280 = 10.19 min./mile $\frac{60.00 \text{ min/hr}}{10.19 \text{ min/mile}}$ = 5.89 MPH

5.89 miles per hour (average) actual travel time = 6.78 loads per 380 minutes per truck

= 13.56 loads per work day

Actual Haulage = 12 loads per work day

PROJECTED TRUCK LOADING AND HAULING PROCEDURE FOR A COMMERCIAL OPERATION

In a commercial operation truck loading (using comparable equipment) will be done in approximately the same amount of time as actually timed for this report. Truck hauling will be cut down with respect to distance traveled. Trucks will not be hauling up and down the hill from the mine to the crusher stockpile. Truck haulage in a commercial operation will be from the working area in the mine to a crusher stockpile just outside the mine portal.

TRUCK HAULING

Calculations to estimate true mean (M) from sample data.

$\Sigma x = 2004$

$N = 32$

$\bar{x} = 62.625$

$\Sigma x^2 = 128,420$

$$S(x) = \sqrt{\frac{\Sigma x^2 - \bar{x} \quad \Sigma x}{N-1}}$$

$$S(x) = \sqrt{\frac{128,420 - 62.625\ (2004)}{32-1}}$$

$$S(x) = \sqrt{\frac{128,420 - 125,500}{31}} = \sqrt{\frac{2,920}{31}} = \sqrt{94.193} = 9.705$$

$$S(\bar{x}) = \frac{S(x)}{\sqrt{N}}$$

$$S(\bar{x}) = \frac{9.705}{\sqrt{32}} = \frac{9.705}{5.656} = 1.715$$

M @ 95% Confidence Level

$M = \bar{x} \pm T\ 0.05 \quad S(\bar{x})$

$M = 62.625 \pm 2.0378 \quad (1.715)$

$M = 62.625 \pm 3.49$ minutes

TRUCK LOADING - DOZE THE MUCK PILE

Calculations to estimate true mean (M) from sample data.

$\Sigma x = 3.11$

$N = 33$

$\bar{x} = .0939$

$\Sigma x^2 = .3001$

$$S(x) = \sqrt{\frac{\Sigma x^2 - \bar{x}\,\Sigma x}{N-1}}$$

$$S(x) = \sqrt{\frac{.3001 - .0939\ (3.11)}{33-1}}$$

$$S(x) = \sqrt{\frac{.3001 - .2920}{32}} = \sqrt{\frac{.0081}{32}} = \sqrt{.00025} = .0159$$

$$S(\bar{x}) = \frac{S(x)}{\sqrt{N}}$$

$$S(\bar{x}) = \frac{0.0159}{\sqrt{33}} = \frac{0.0159}{5.7445} = .0027$$

M @ 95% Confidence Level

$M = \bar{x} \pm T\ 0.05\ S(\bar{x})$

$M = .0939 \pm 2.0399\ \ (.0027)$

$M = .0939 \pm .0055$ minutes

TRUCK LOADING - LOAD THE BUCKET

Calculations to estimate true mean (M) from sample data.

$$\Sigma x = 4.91$$

$$N = 40$$

$$\bar{x} = 0.12275$$

$$\Sigma x^2 = .6166$$

$$S(x) = \sqrt{\frac{\Sigma x^2 - \bar{x}\,\Sigma x}{N-1}}$$

$$S(x) = \sqrt{\frac{.6166 - .12275\,(4.91)}{40-1}}$$

$$S(x) = \sqrt{\frac{.6166 - .6027}{39}} = \sqrt{\frac{.0139}{39}} = \sqrt{.0004} = .02$$

$$S(\bar{x}) = \frac{S(x)}{\sqrt{N}}$$

$$S(\bar{x}) = \frac{.02}{\sqrt{40}} = \frac{.02}{6.3245} = .003$$

M @ 95% Confidence Level

$$M = \bar{x} \pm T\,0.05 \quad S(\bar{x})$$

$$M = .122 \pm 2.021\,(.003)$$

$M = .122 \pm .006$ minutes

TRUCK LOADING - BACK AND TURN

Calculations to estimate true mean (M) from sample data.

$\delta x = 5.60$

$N = 36$

$\bar{x} = .15555$

$\delta x^2 = .9135$

$$S(x) = \sqrt{\frac{\delta x^2 - \bar{x}\,\delta x}{N-1}}$$

$$S(x) = \sqrt{\frac{.9135 - .1555\,(5.60)}{36-1}}$$

$$S(x) = \sqrt{\frac{.9135 - .8710}{35}} = \sqrt{\frac{.0425}{35}} = \sqrt{.00121} = .034846$$

$$S(\bar{x}) = \frac{S(\bar{x})}{\sqrt{N}}$$

$$S(\bar{x}) = \frac{.034846}{\sqrt{36}} = \frac{.034846}{6} = .0058$$

M @ 95% Confidence Level

$M = \bar{x} \pm T\ 0.05\ \ S(\bar{x})$

$M = .15555 \pm 2.0294\ (.0058)$

$M = .15555 \pm .013$ minutes

TRUCK LOADING - DUMP THE BUCKET

Calculations to estimate true mean (M) from sample data.

$\Sigma x = 3.46$

$N = 38$

$\bar{x} = .0910$

$\Sigma x^2 = .3666$

$$S(x) = \sqrt{\frac{\Sigma x^2 - \bar{x}\ \Sigma x}{N-1}}$$

$$S(x) = \sqrt{\frac{.3666 - (.0910)\ 3.46}{38-1}}$$

$$S(x) = \sqrt{\frac{.3666 - .3148}{37}} = \sqrt{\frac{.0518}{37}} = \sqrt{.0014} = .0374$$

$$S(\bar{x}) = \frac{S(x)}{\sqrt{N}}$$

$$S(\bar{x}) = \frac{.0374}{\sqrt{38}} = \frac{.0374}{6.164} = .006$$

M @ 95% Confidence Level

$M = \bar{x} \pm T\ 0.05\ \ S(\bar{x})$

$M = .091 \pm 2.0252\ \ (.006)$

$M = .091 \pm .012$ minutes

TRUCK LOADING - TRAVEL EMPTY

Calculations to estimate true mean (M) from sample data.

$\Sigma x = 2.85$

$N = 32$

$\bar{x} = .089$

$\Sigma x^2 = .2629$

$$S(x) = \sqrt{\frac{\Sigma x^2 - \bar{x}\,\Sigma x}{N-1}}$$

$$S(x) = \sqrt{\frac{.2629 - .089\ (2.85)}{32-1}}$$

$$S(x) = \sqrt{\frac{.2629 - .2536}{31}} = \sqrt{\frac{.0093}{31}} = \sqrt{.0003} = .0173$$

$$S(\bar{x}) = \frac{S(x)}{\sqrt{N}}$$

$$S(\bar{x}) = \frac{.0173}{\sqrt{32}} = \frac{.0173}{5.6568} = .003$$

M @ 95% Confidence Level

$M = \bar{x} \pm T\ 0.05\ \ S(\bar{x})$

$M = .089 \pm 2.6378\ \ (.003)$

$M = .089 \pm .006$ minutes

MAN/MACHINE TIME CHART

Loading and Hauling - Anvil Points Mine

November 1975

	ELEMENT	TIME	CUMULATIVE TIME
	Doze	.07	.07
	Load	.11	.18
	Back and Turn	.08	.26
	Travel Loaded	.14	.40
1	Dump	.07	.47
	Travel Empty	.06	.53
	Doze	.08	.61
	Load	.12	.73
	Back and Turn	.14	.87
	Travel Loaded	.16	1.03
2	Dump	.09	1.12
	Travel Empty	.08	1.20
	Doze	.10	1.30
	Load	.11	1.41
	Back and Turn	.14	1.55
	Travel Loaded	.16	1.71
3	Dump	.18	1.89
	Travel Empty	.12	2.01
	Doze	-	2.01
	Load	.12	2.13
	Back and Turn	-	2.13
	Travel Loaded	.17	2.30
4	Dump	.17	2.47
	Travel Empty	-	2.47
	Doze	.06	2.53
	Load	.11	2.64
	Back and Turn	.12	2.76
	Travel Loaded	.18	2.94
5	Dump	.04	2.98
	Travel Empty	.08	3.06
	Doze	.08	3.14
	Load	.13	3.27
	Back and Turn	.16	3.43
	Travel Loaded	.12	3.55
6	Dump	.06	3.61
	Travel Empty	.05	3.66
	Doze	.08	3.74
	Load	.14	3.88
	Back and Turn	.11	3.99
	Travel Loaded	.16	4.15

MAN/MACHINE TIME CHART

Loading and Hauling - Anvil Points Mine

November 1975

	ELEMENT	TIME	CUMULATIVE TIME
7	Dump	.07	4.22
	Travel Empty	.07	4.29
	Doze	.11	4.40
	Load	.09	4.49
	Back and Turn	.16	4.65
	Travel Loaded	.21	4.86
8	Dump	.07	4.93
	Travel Empty	.08	5.01
	Doze	.10	5.11
	Load	.13	5.24
	Back and Turn	.16	5.40
	Travel Loaded	.20	5.60
9	Dump	.07	5.67
	Travel Empty	.13	5.80
	Doze	.11	5.91
	Load	.13	6.04
	Back and Turn	.12	6.16
	Travel Loaded	.16	6.32
10	Dump	.09	6.41
	Travel Empty	.08	6.49
	Doze	.11	6.60
	Load	.08	6.68
	Back and Turn	.14	6.82
	Travel Loaded	.19	7.01
11	Dump	.10	7.11
	Travel Empty	-	7.11
	Doze	.11	7.22
	Load	.14	7.36
	Back and Turn	.24	7.60
	Travel Loaded	.21	7.81
12	Dump	.06	7.87
	Travel Empty	.12	7.99
	Doze	.10	8.09
	Load	.10	8.19
	Back and Turn	.18	8.37
	Travel Loaded	.12	8.49

MAN/MACHINE TIME CHART

Loading and Hauling - Anvil Points Mine

November 1975

	ELEMENT	TIME	CUMULATIVE TIME
13	Dump	.06	8.55
	Travel Empty	.08	8.63
	Doze	.08	8.71
	Load	.13	8.84
	Back and Turn	-	8.84
	Travel Loaded	-	8.84
14	Dump	.08	8.92
	Travel Empty	.11	9.03
	Doze	.09	9.12
	Load	.12	9.24
	Back and Turn	.17	9.41
	Travel Loaded	.16	9.57
15	Dump	.07	9.64
	Travel Empty	.09	9.73
	Doze	.11	9,84
	Load	.17	10.01
	Back and Turn	.18	10.19
	Travel Loaded	.12	10.31
16	Dump	.09	10.40
	Travel Empty	.09	10.49
	Doze	.08	10.57
	Load	.14	10.71
	Back and Turn	.21	10.92
	Travel Loaded	.15	11.07
17	Dump	.11	11.18
	Travel Empty	.09	11.27
	Doze	.12	11.39
	Load	.14	11.53
	Back and Turn	.19	11.72
	Travel Loaded	.19	11.91
18	Dump	.22	12.13
	Travel Empty	-	12.13
	Doze	.06	12.19
	Load	.11	12.30
	Back and Turn	.11	12.41
	Travel Loaded	.14	12.55

MAN/MACHINE TIME CHART

Loading and Hauling - Anvil Points Mine

November 1975

	ELEMENT	TIME	CUMULATIVE TIME
19	Dump	.06	12.61
	Travel Empty	.09	12.70
	Doze	.09	12.79
	Load	.11	12.90
	Back and Turn	.09	12.99
	Travel Loaded	.19	13.18
20	Dump	.08	13.26
	Travel Empty	.10	13.36
	Doze	.09	13.45
	Load	.14	13.59
	Back and Turn	.13	13.72
	Travel Loaded	.17	13.89
21	Dump	.08	13.97
	Travel Empty	.08	14.05
	Doze	.09	14.14
	Load	.13	14.27
	Back and Turn	.13	14.40
	Travel Loaded	.19	14.59
22	Dump	.09	14.68
	Travel Empty	.09	14.77
	Doze	.07	14.84
	Load	.12	14.96
	Back and Turn	.11	15.07
	Travel Loaded	.22	15.29
23	Dump	.14	15.43
	Travel Empty	.09	15.52
	Doze	-	15.52
	Load	.11	15.63
	Back and Turn	.17	15.80
	Travel Loaded	-	15.80
24	Dump	.08	15.88
	Travel Empty	.09	15.97
	Doze	-	15.97
	Load	.11	16.08
	Back and Turn	.17	16.25
	Travel Loaded	-	16.25

MAN/MACHINE TIME CHART

Loading and Hauling - Anvil Points Mine

November 1975

	ELEMENT	TIME	CUMULATIVE TIME
25	Dump	.08	16.33
	Travel Empty	.09	16.42
	Doze	-	16.42
	Load	.08	16.50
	Back and Turn	.16	16.66
	Travel Loaded	.16	16.82
26	Dump	.07	16.89
	Travel Empty	.08	16.97
	Doze	.11	17.08
	Load	.15	17.23
	Back and Turn	.19	17.42
	Travel Loaded	.11	17.53
27	Dump	.07	17.60
	Travel Empty	.07	17.67
	Doze	.10	17.77
	Load	.16	17.93
	Back and Turn	.17	18.10
	Travel Loaded	.11	18.21
28	Dump	.08	18.29
	Travel Empty	.10	18.39
	Doze	.11	18.50
	Load	.13	18.63
	Back and Turn	.17	18.80
	Travel Loaded	.10	18.90
29	Dump	.09	18.99
	Travel Empty	.09	19.08
	Doze	.11	19.19
	Load	.14	19.33
	Back and Turn	.21	19.54
	Travel Loaded	.13	19.67
30	Dump	.10	19.77
	Travel Empty	.10	19.87
	Doze	.11	19.98
	Load	.16	20.14
	Back and Turn	-	20.14
	Travel Loaded	.18	20.32
31	Dump	-	20.32
	Travel Empty	-	20.32
	Doze	.07	20.39
	Load	.13	20.52
	Back and Turn	.16	20.68
	Travel Loaded	.16	20.84

MAN/MACHINE TIME CHART

Loading and Hauling - Anvil Points Mine

November 1975

	ELEMENT	TIME	CUMULATIVE TIME
32	Dump	.08	20.92
	Travel Empty	.07	20.99
	Doze	.11	21.10
	Load	.12	21.22
	Back and Turn	.16	21.38
	Travel Loaded	.14	21.52
33	Dump	.06	21.58
	Travel Empty	.08	21.66
	Doze	.10	21.76
	Load	.12	21.88
	Back and Turn	.15	22.03
	Travel Loaded	.17	22.20
34	Dump	.07	22.27
	Travel Empty	.09	22.36
	Doze	-	22.36
	Load	.13	22.49
	Back and Turn	.17	22.66
	Travel Loaded	.12	22.78
35	Dump	.07	22.85
	Travel Empty	-	22.85
	Doze	.11	22.96
	Load	.11	23.07
	Back and Turn	.19	23.26
	Travel Loaded	.18	23.44
36	Dump	.11	23.55
	Travel Empty	-	23.55
	Doze	-	23.55
	Load	.12	23.67
	Back and Turn	.18	23.85
	Travel Loaded	.21	24.06
37	Dump	.11	24.17
	Travel Empty	.10	24.27
	Doze	.12	24.39
	Load	.10	24.49
	Back and Turn	.11	24.60
	Travel Loaded	.22	24.82

MAN/MACHINE TIME CHART

Loading and Hauling - Anvil Points Mine

November 1975

	ELEMENT	TIME	CUMULATIVE TIME
38	Dump	.16	24.98
	Travel Empty	.11	25.09
	Doze	-	25.09
	Load	.09	25.18
	Back and Turn	.17	25.35
	Travel Loaded	.23	25.58
39	Dump	.08	25.66
	Travel Empty	-	25.66
	Doze	.06	25.72
	Load	.13	25.85
	Back and Turn	-	25.85
	Travel Loaded	.20	26.05
40	Dump	-	26.05
	Travel Empty	-	26.05

MAN/MACHINE TIME CHART

Actual Truck Hauling Times (Round Trip) From Mine to Crusher Stockpile

All Times in Minutes

53 Minutes	60 Minutes	60 Minutes
78 Minutes	56 Minutes	66 Minutes
81 Minutes	60 Minutes	51 Minutes
60 Minutes	53 Minutes	68 Minutes
71 Minutes	52 Minutes	
65 Minutes	55 Minutes	
90 Minutes	58 Minutes	
51 Minutes	56 Minutes	
72 Minutes	60 Minutes	
74 Minutes	60 Minutes	
81 Minutes	60 Minutes	
54 Minutes	63 Minutes	
56 Minutes	61 Minutes	
60 Minutes	59 Minutes	

SUMMARY

Total Time	Occurrence	Mean	Standard Deviation	Per Cent Standard Deviation
2,004.00	32	62.625	9.70	15%

MAN/MACHINE TIME CHART

Loading and Hauling - Anvil Points Mine

November 1975

SUMMARY SHEET

Element	Total Time	Occurrences of Cycle Elements	Mean	Standard Deviation	Per Cent Standard Deviation
1. Doze	3.11	33	.09	.02	19%
2. Load	4.91	40	.12	.02	16%
3. Back and Turn	5.60	36	.16	.04	22%
4. Travel Loaded	6.13	37	.17	.03	21%
5. Dump	3.46	38	.09	.04	41%
6. Travel Empty	2.84	32	.09	.02	19%
	26.05				